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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

INQUIRY INTO QUESTIONS OF GENERAL INTEREST.

(Decision taken by the Permanent Commission at its Meeting held on July 9th, 1938.)

[535. 114 & 656. 22]

QUESTION I.

Methods used to speed up passenger trains and the resulting expenditure.

In particular, operating by means of railcars and the financial results obtained by this method.

REPORT

(Great Britain, Dominions and Colonies, North and South America, China, Japan)

by T. W. ROYLE,

Chief Operating Manager, London Midland and Scottish Railway,

and F. E. HARRISON,

Engineer, North Eastern Area, London and North Eastern Railway.

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PART ONE.

METHODS USED TO SPEED UP PASSENGER TRAINS AND THE COST THEREOF.

Foreword.

Although during the past five years considerable accelerations to passenger services have been achieved by railways in every part of the world, such action has not been universal.

Our report must of necessity confine itself to the action of those Administrations who have found themselves able to provide us with examples of what they have done, and, in this connection, we desire to acknowledge our indebtedness to the following Administrations for the information with which they have provided us.

<i>Argentina.</i>	Buenos Aires and Pacific Railway.
<i>Burma.</i>	Burma Railways.
<i>Ceylon.</i>	Ceylon Government Railway.
<i>Egypt.</i>	Egyptian State Railways.
<i>Great Britain.</i>	Great Western Railway, London Midland and Scottish Railway, London and North Eastern Railway, Southern Railway.
<i>India.</i>	Bombay, Baroda and Central India Railway, Great Indian Peninsula Railway, South Indian Railway.
<i>Iraq.</i>	Iraq State Railways.
<i>United States of America.</i>	Pennsylvania Railroad.

Introduction.

The physical conditions and the type and density of the traffic obtaining on the lines of these Administrations have

naturally influenced the form of service acceleration executed and the methods which have been adopted to this end.

The operating speeds customary prior to 1934 vary considerably; the standard of speed offered in Great Britain and the East of the United States being in excess of that offered, for example, in Indian and Eastern territories.

Broadly, the Administrations fall into two categories; those operating a dense traffic at a fast speed and those operating a relatively light traffic at a moderate speed. In general the length of journey on the former is considerably less than that on the latter. The United States provides an exception since in that country long journeys are covered at a high rate of speed.

There is a field for passenger service acceleration on both types of Administration. As will presently be developed the accelerations on dense-traffic lines are not as a rule spectacular from the point of view of time saved per journey but the number of services affected per day is high. On light-traffic lines the time saved per journey is greater owing to the longer journeys made, but the number of services affected are seldom more than one in each direction each day.

On those railways where high speeds have been customary in the past, there has recently been a tendency to operate certain spectacular runs at even higher speeds than heretofore.

For the purposes of this report we intend terming trains running at start to stop speeds of 67 m. p. h. or over as "high-speed" trains.

The following table is given as an example of the fast start to stop runs operated by the Administrations under review.

Passenger train mileage at booked start to stop speeds of over 60 m.p.h. and 67 m.p.h.

ADMINISTRATION.	Booked passenger train mileage, July 1938, at start to stop speeds of:		Percentage of train mileage at 60 m.p.h. or over to total pas- senger train mileage.
	67 m. p. h. or over.	60 m. p. h. or over.	
<i>Great Western</i>	313 (3)	2 116 (26)	1.7
<i>London Midland and Scottish.</i>	—	6 317 (63)	1.9
<i>London and North Eastern. .</i>	1 292 (6)	2 889 (22)	1.4
<i>Pennsylvania</i>			
Steam	1 913 (33)	7 837 (180)	11.3
Electric	819 (8)	3 602 (52)	14.1
Total	2 732 (41)	11 439 (232)	12.1

Notes. — The figures in brackets indicate the number of individual runs making up each aggregate mileage.
Particulars for the Pennsylvania Railroad, from *The Railway Magazine*, December 1938, page 395.

The high traffic density and considerable local short-journey traffic on British railways is unfavourable to the operation of high-speed train mileage to the extent possible on the Pennsylvania. The Southern Railway which carries a greater proportion of short-distance passenger traffic than the other main-line railways in Great Britain does not figure in the table, but, although they operate no trains at start to stop speeds of over 60 m. p. h., many trains run at pass to pass speeds well in excess of this figure for considerable distances.

The reasons given for the speeding up of passenger services are diverse. In general, action has been prompted by a desire to satisfy public demand for quicker travel.

Road competition has been an important factor in some cases but mainly for short-distance traffic. Short-distance road competition has been severe for example in Burma, Ceylon, Egypt, and India.

Air competition has influenced the acceleration of express services running distances up to 400 miles on the Pennsylvania Railroad.

Details of individual reports are as

follows : The Great Western state that train accelerations have not been directly prompted by road and air competition but, rather, by the public demand for faster travel.

The London Midland and Scottish admit that road and air competition have been important factors in dictating their policy of train acceleration.

The London and North Eastern state that the accelerations they have made are part of a progressive policy which they have adopted to meet all forms of competition.

The accelerations carried out by the Southern have not been due to road competition.

The Great Indian Peninsula report that road competition has been confined to short-distance traffic, while the South Indian state that it has caused them to accelerate their trains on almost all sections of line.

The Burma Railways report severe road competition with their branch line services.

The Buenos Aires and Pacific mention that the improvement of roads parallel with their lines has increased road competition and that air competition

with their main-line services has influenced them in speeding up their trains.

On the Pennsylvania air services are a competitive feature in such territory as New York-Philadelphia, New York-Washington, and New York-Pittsburgh. The timings of trains in this area are

worked out with such competition in mind. For longer distances the time differential between air and rail services is too great. The Pennsylvania have found that road competition has not required any appreciable quickening of train services.

I. — PASSENGER TRAIN SERVICES ACCELERATED SINCE JANUARY 1934.

The Administrations were asked to state the principal services which had been accelerated between January 1934 and July 1938. The replies have been co-ordinated as far as possible in Table 1.

The particulars must be taken as examples of the type of service accelerations carried out rather than as a complete catalogue of what has been achieved.

The Great Western report that since 1934 their main and branch-line services have been accelerated generally and 4 926 minutes have been saved daily.

On the London Midland and Scottish, an active policy has been pursued of accelerating all classes of service and a large number of local trains have been speeded up in addition to the principal expresses. In all 27 535 minutes have been saved daily.

The London and North Eastern have not only accelerated their ordinary services, both main and branch, but, in the case of six runs, have effected considerable savings in journey times by the introduction of high-speed services running at start to stop speeds of 67 m. p. h. and over.

The Southern have systematically accelerated their passenger services on main and some branch lines since January, 1934. Improvements to main line services both steam and electric amount to 28 220 minutes a week. The change of steam to electric traction has provided opportunities for reducing journey times as illustrated in Table 1. In addi-

tion some 100 steam trains on the following services have been accelerated.

London (Charing Cross) and Deal	87 miles.
London (Victoria) and Ramsgate .	79 miles.
London (Waterloo) and Exmouth.	176 miles.
London (Waterloo) a. Ilfracombe	226 miles.
London (Waterloo) a. Weymouth	143 miles.
London (Waterloo) and Exeter .	172 miles.
Brighton and Bournemouth . . .	92 miles.
Brighton and Exeter.	170 miles.

The Bombay, Baroda and Central India have accelerated six important mail trains, and, by an extension of the Bombay suburban electric service from Borivli to Virar, have been able to quicken certain suburban trains.

The Great Indian Peninsula report that on their main lines two express trains between Bombay and Poona and one express between Bombay and Raichur were accelerated. A few suburban trains were accelerated to a slight extent. From April 1937, the timings of certain trains on branch lines were accelerated also.

The South Indian have made accelerations on main, branch and suburban lines.

Not included in Table 1, the Ceylon Government Railway report that most of their services on important lines were accelerated with the introduction of a revised time table in 1937. The distances covered average 150 miles with 4 or 5 intermediate stops. Savings of from 30 to 60 minutes have been achieved on these services.

Name of Administration. (Gauge of lines on which accelerated services operate.)	SERVICE.	Method of traction.		Distance, miles.	No. of services considered.		Average overall journey time.		Average No. of stops per train.		Average reduction in overall journey time
		1934	1938		1934	1938	1934	1938	1934	1938	
GREAT BRITAIN. <i>Great Western</i> (4' 8 1/2").	London and Bristol (« Bristolian » Service)	Steam.	Steam.	118 1/4 down, 117 3/4 up.	(See note)	2	H. M. 2 0	H. M. 1 45	Non-stop	Non-stop	Mins 45
	London and Bristol . . .	Steam.	Steam.	118 1/4	3	3	2 42	2 22	4 3	3	20
	Weston-super-Mare & Lond.	Steam.	Steam.	137 1/2	1	1	3 15	2 47	5	4	28
	London and Plymouth . .	Steam.	Steam.	225 1/2	2	2	4 53	4 41 1/2	5.5	7	41 1/2
	London and Neyland . . .	Steam.	Steam.	263 1/4	1	1	7 13	6 57	23	22	16
	London and Hereford . .	Steam.	Steam.	149 3/4	1	1	4 29	3 42	21	17	47
	Malvern Wells and London	Steam.	Steam.	130	1	1	5 2	2 55	29	8	127
	Birmingham and London	Steam.	Steam.	110 1/2	1	1	2 30	2 15	6	5	45
	Note.—New service compared with best service in 1934.										
	London and Glasgow . .	Steam.	Steam.	401 1/2	4	4	7 56	6 45	3.75	4.25	71
<i>London Midland and Scottish</i> . (4' 8 1/2").	London and Liverpool . .	Steam.	Steam.	193 1/2	5	5	3 43	3 27	3	2.25	16
	London and Manchester .	Steam.	Steam.	188 3/4	4	4	3 46	3 36 1/2	3	3	9 1/2
	London and Birmingham .	Steam.	Steam.	112 3/4	10	10	2 5	2 0	1 7	1 7	5
	London and Nottingham .	Steam.	Steam.	123 1/2	12	12	2 30 1/2	2 19	2.5	2.7	11 1/2
	London and Leicester . .	Steam.	Steam.	99	16	16	1 51	1 42	0.9	0.6	9
	London and Newcastle . .	Steam.	Steam.	268	(See note)	2	5 7	3 57	4	1	70
	London and Edinburgh . .	Steam.	Steam.	392	(See note)	2	7 45	6 0	4	2	105
	London and Leeds . . .	Steam.	Steam.	186	(See note)	2	3 13	2 43	Non-stop	Non-stop	30
	London and Hull . . .	Steam.	Steam.	197	...	...	4 4	3 30	6	1	34
	London and Scarborough .	Steam.	Steam.	230	...	...	4 10	3 55	4	1	45
<i>London and North Eastern</i> . (4' 8 1/2").	London and Norwich . . .	Steam.	Steam.	115	...	...	2 30	2 10	2	1	20
	Newcastle-Tynemouth-Newcastle (Circle) . . .	Multiple unit, electric.	Multiple unit, electric.	21	...	...	1 3	- 53	18	18	10
	Edinburgh and Aberdeen .	Steam.	Steam.	131	...	...	3 31	3 0	8	4	24
	Edinburgh and Glasgow .	Steam.	Steam.	47	...	4	1 2	- 58	1	Non-stop	4
	Note.—New service compared with best service in 1934.										
	London and Bournemouth .	Steam.	Steam.	108	17	17	2 26	2 19	3.6	3.2	7
	London and Portsmouth Harbour	Steam.	Multiple unit, electric.	74	9	46	1 58	1 35	4	3	23
	London and Eastbourne . .	Steam.	do.	66	18	20	1 40	1 25	4	3	15
	London and Hastings (via Lewes)	Steam.	do.	77	9	49	2 10	1 55	8	7	15
	Harbour (via Horsham) . .	Steam.	do.	88	9	46	2 49	2 12	12	11	37
<i>Southern</i> . (4' 8 1/2").	Brighton and Portsmouth Harbour	Steam.	do.	45	15	16	1 32	1 9	10	9	23
	Brighton and Hastings . .	Steam.	do.	45	15	16	1 32	1 21	10	17	44
	Brighton and Hastings . .	Steam.	do.	40	16	30	1 23	1 17	9	17	6
	Brighton and Hastings . .	Steam.	do.	40	16	30	1 23	1 17	9	17	6

TABLE 1. — Examples of passenger train services accelerated between January 1934 and July 1938. (Concl.)

Name of Administration. (Gauge of lines on which accelerated services operate.)	SERVICE.	Method of traction.		Distance, miles.	No. of services considered.		Average overall journey time.		Average No. of stops per train.		Average reduction in overall journey time.
		1934.	1938.		1934	1938	1934	1938			
INDIA.											
<i>Bombay, Baroda and Central India.</i> (5' 6").	Bombay and Delhi . . .	Steam.	Steam.	860 1/4	2	2	H. M.	H. M.	20	18.5	50
	Bombay and Ahmedabad . .	Steam.	Steam.	305 1/2	2	2	23 55	23 5	40	40	20
	Bombay and Viramgam . .	Steam.	Steam.	345 3/4	2	2	9 42	9 22	14.5	14.5	56
	Bombay and Poona . . .	Electric engine.	Electric engine.	119	2	2	12 15	11 19	8	8	44
	Delhi and Jhansi . . .	Steam.	Steam.	255	2	2	3 54	3 10	...	...	114
<i>Great Indian Peninsula.</i> (5' 6").	Madras and Trivandrum . .	Steam.	Steam.	511 1/4	2	2	13 53	12 2	51	36	86
	Vridhachalam and Salem Jc.	Steam.	Steam.	86 1/4	...	...	18 15	16 49	43	24	45
	Dindignl and Pollachi . .	Steam.	Steam.	75 1/4	...	...	3 56	3 11	13	13	23
	Madras Beach and Tambaram	Multiple unit, electric.	Multiple unit, electric.	18	...	...	2 57	2 34	12	12	40
							— 50	— 40			
BURMA.											
<i>Burma Railways</i> (Metre).	Rangoon and Mandalay . .	Steam.	Steam.	385 1/2	4	4	15 41	14 25	45	44	76
UNITED STATES OF AMERICA.											
<i>Pennsylvania.</i> (4' 8 1/2").	New York and Chicago . .	Electric eng. 106.7 miles. Steam	Electric eng. 189.9 miles. Steam	902.9	43	44	20 4	18 20	23	20	104
	New York and St. Louis. .	796.2 miles. Electric eng. 106.7 miles. Steam	713.0 miles. Electric eng. 189.9 miles. Steam	1 047.8	6	6	22 53	21 19	20	17	94
	New York and Washington.	941.1 miles. Electric eng. 116.3 miles. Steam	857.9 miles. Electric engine.	224.8	29	30	4 32	4 03	8.4	7.6	29
	New York and Philadelphia	108.5 miles. Electric engine.	Electric engine.	91.3	33	33	1 51	1 41	6	5	40
ARGENTINE.											
<i>Buenos Aires Pacific.</i> (5' 6").	Buenos Aires and Mendoza. Rufino and San Rafael . .	Steam. Steam.	Steam. Steam.	650 361	2 2	2 2	23 50 16 0	15 5 10 5	... ...	11 ...	525 355

On the Egyptian State Railways, a general recast of the express and local train services was made in 1934 and acceleration effected thereby. Local trains were further accelerated in 1935 and 1938. In addition the introduction of a diesel car service between Cairo and Helwan-les-Bains enabled running times to be reduced.

The Burma Railways report accelerations to the mail and express services between Rangoon and Mandalay, where a saving of 103 minutes has been achieved on a run of 385 1/2 miles, with the elimination of only one stop.

On the Pennsylvania there has been a progressive quickening of passenger schedules since January 1934 on main lines, primarily in through services, but suburban services have also been improved in the main-line territory. The quickening can be traced back several years prior to 1934. In April 1932 the charging of « extra fares » was eliminated. Previously an « extra fare » of \$ 1.20 for each hour's saving in time under 28 hours had been charged on all trains between New York and Chicago, St. Louis, Cincinnati, Cleveland, etc., with corresponding extra fares to and from intermediate points. By abolishing

the extra fare it was possible to eliminate what were known as normal-fare (28 hours) trains between New York and Chicago, and New York and St. Louis, and to consolidate trains on improved schedules.

In contrast to the considerable accelerations on main lines, very little, if any, quickening of schedules on secondary or branch lines has been achieved by the Pennsylvania. Authorised maximum speed has been decreased, rather than increased, in territories where passenger travel is light and the passenger train service is kept to a minimum.

The Buenos Aires and Pacific have carried out a general acceleration of main-line trains, and, in particular, have inaugurated a new express day train between Buenos Aires and Mendoza. Branch-line services have been accelerated where feasible.

Examples of accelerated services.

In order that the type of accelerated service operated by the various Administrations, as well as the relevant operating conditions and other circumstances, may be appreciated the better, a list of examples are set out in Table 2.

II. — METHODS USED TO INCREASE THE OVERALL SPEED OF PASSENGER SERVICES.

The methods that have been used to accelerate passenger services have naturally been governed by the conditions peculiar to each Administration. In some cases the standard of speed was already high in 1934, while in others there was at that time a not inconsiderable field for improvement.

In Great Britain, the Great Western, the London Midland and Scottish, the London and North Eastern, and in part, the Southern, provide examples of accelerations under dense-traffic conditions. The Southern, as far as its elec-

trified lines are concerned, is an example of acceleration by changing from steam to multiple-unit electric equipment.

In India, the Bombay, Baroda and Central India, the Great Indian Peninsula and the South Indian; in Burma, the Burma Railway; and, in the Argentine, the Buenos Aires and Pacific, illustrate what can be achieved over routes when traffic is relatively light but physical conditions are adverse.

The Pennsylvania in America offers an outstanding example of what can be

TABLE 2. — Typical examples

ADMINISTRATION.	GREAT WESTERN.	
EXAMPLE.	A.	B.
<i>Service</i>	London-Bristol. Bristol-London. « The Bristolian ».	Exeter-London.
<i>Type of train.</i>	High speed — Non-stop. 10.0 a. m. from London. 4.30 p. m. from Bristol.	Express, 2 stops. 8.50 a. m. from Exeter.
<i>Method of traction.</i>	Steam.	Steam.
<i>Route</i>	To Bristol via Bath. From Bristol via Badminton.	Via Westbury and Reading.
<i>Route mileage</i>	To Bristol, 118 1/4 miles. From Bristol, 117 1/2 miles.	173 1/2 miles.
<i>Mileage of single line worked over.</i>	Nil.	Nil.
<i>Daily number of similar services.</i>	2	1
<i>Type of rolling stock</i>	Eight-wheeled corridor coaches.	Eight-wheeled corridor coaches.
<i>Weight of the trains (Tare, long tons).</i>	230 tons.	260 tons
<i>Overall journey time</i>	1 h. 45 m. Both directions.	3 hours.
<i>Speed.</i>	Start to stop — to Bristol 67.6 m. p. h.; from Bristol 67.1 m.p.h. — Highest pass to pass booking 13 miles at 79.1 m. p. h.	Start to stop Exeter to Taunton 30 3/4 miles at 52.7 m. p. h. Taunton to Westbury, 47 1/4 miles at 59.0 m. p. h. Westbury to London, 95 1/2 miles at 62.4 m. p. h.
<i>Gradients.</i> Note. — Under 1 in 250 = « Easy ». — 1 in 250 to 1 in 150 = « Moderate ». — Over 1 in 150 = « Heavy ».	Easy, except for 4 miles of heavy gradients rising towards London.	Easy for 141 1/2 miles. Moderate for 18 miles. Heavy for 14 miles.

f accelerated services.

LONDON MIDLAND AND SCOTTISH.					
C.		D.		E.	
London-Glasgow. Glasgow-London. « The Coronation Scot ».		Liverpool-London.		London-Birmingham. Birmingham-London.	
Fast afternoon express. intermediate stop at Carlisle, 99 miles from London, both north and South bound.		Day services at 10.10 a. m. 2.10 p. m. 4.10 p. m. 5.25 p. m. The 2.10 p. m. and 4.10 p. m. stop twice, the 10.10 a. m. and 5.25 p. m. stop once.		Day services. With one exception these service make one intermediate stop.	
Steam.		Steam.		Steam.	
Via Rugby, Crewe and Carlisle.		Via Crewe and Rugby.		Via Rugby and Coventry.	
401 1/2 miles.		193 1/2 miles.		112 3/4 miles.	
Nil.		Nil.		Nil.	
2		4		8	
Specially built for this service. general construction follows the company's standard practice.		Standard coaching stock.		Standard coaching stock.	
297 tons (limited).		Tonnage of trains limited as follows:		Trains limited to :	
		Train. Class of engine.		400 tons with class 6 engine or 350 tons with class 5 X engine.	
		7 6 5 X			
		10.10 a. m. 530 400 —			
		2.10 p. m. 420 360 320			
		4.10 p. m. — 380 330			
		5.25 p. m. 420 360 320			
6 h. 30 m. Both directions.		10.10 a. m. } 3 h. 20 m. 2.10 p. m. } 4.10 p. m. } 3 h. 30 m. 5.25 p. m. } 3 h. 15 m.		7 services with one stop, 1 h. 55 m. One service with 2 stops, 2 hours.	
Maximum speed limited to 90 m.p.h. Average speed 299 miles London to Carlisle, and Carlisle to London 6.4 m. p. h. Overall speed Lon- don to Glasgow and Glasgow to London 61.7 m. p. h.		Maximum speed limited to 90 m.p.h. — 10.10 a. m. runs 189.74 miles Mossley Hill to London at 60.23 m. p. h. — 2.10 p. m. runs 158.06 miles Crewe to London at 62.39 m. p. h. — 4.10 p. m. runs 97.11 miles Nuneaton to London at 63.33 m. p. h. — 5.25 p. m. runs 158.06 miles Crewe to London at 64.08 m. p. h.		Maximum speed limited to 90 m.p.h. — 7 of the 8 services take 115 mi- nutes, with one intermediate stop, 58.9 m. p. h. — The remaining service takes 120 minutes with three intermediate stops and co- vers the 65.09 miles Rugby to Watford in 60 minutes at 65.09 m. p. h.	
Northbound.		Northbound.		Northbound.	
Easy. 347 1/2 miles.		Easy. 186 1/2 miles.		Easy. 110 3/4 miles.	
Moderate 19 miles.		Moderate 4 miles.		Heavy 2 miles.	
Heavy 35 miles.		Heavy 3 miles.		Southbound.	
Southbound.		Southbound.		Easy. 112 3/4 miles.	
Easy. 336 1/2 miles.		Easy. 184 1/2 miles.			
Moderate 19 miles.		Moderate 3 miles.			
Heavy 46 miles.		Heavy 6 miles.			

TABLE 2. — Typical exam

ADMINISTRATION.	LONDON MIDLAND AND SCOTTISH.	
EXAMPLE.	F.	G.
<i>Service</i>	London-Leicester. Leicester-London.	London-Newcastle. Newcastle-London. « The Silver Jubilee ».
<i>Type of train.</i>	Day services. No intermediate stops.	High speed.
<i>Method of traction.</i>	Steam.	Steam.
<i>Route</i>	Via Kettering.	Via Darlington.
<i>Route mileage</i>	99 miles.	268 1/4 miles.
<i>Mileage of single line worked over.</i>	Nil.	Nil.
<i>Daily number of similar services.</i>	Three, London to Leicester. Five, Leicester to London.	2
<i>Type of rolling stock</i>	Standard coaching stock.	Bogie vestibule articulated
<i>Weight of the trains (Tare, long tons).</i>	Trains limited to : 300 tons with class 5 X engine. 255 tons with class 5 engine. 220 tons with class 4 engine.	246 tons.
<i>Overall journey time</i>	1 h. 39 m., both directions.	4 hours, both directions.
<i>Speed.</i>	Maximum speed limited to 85 m.p.h. The 8 services all run non-stop Lon- don to Leicester, or Leicester to London, at 60 m. p. h.	Average speed excluding sta- stops of 67.65 m. p. h. (both vices). Maximum permissible speed 90 m.
<i>Gradients.</i> <i>Note. — Under 1 in 250 =</i> <i>« Easy ». — 1 in 250 to 1 in</i> <i>150 = « Moderate ». — Over</i> <i>1 in 150 = « Heavy ».</i>	<i>Northbound.</i> Easy. 63 miles. Moderate 27 miles. Heavy 9 miles. <i>Southbound.</i> Easy. 66 miles. Moderate 25 miles. Heavy 8 miles.	<i>Northbound.</i> Easy. 231 3/4 m. Moderate 32 1/2 m. Heavy 4 miles. <i>Southbound.</i> Easy. 236 3/4 m. Moderate 29 1/2 m. Heavy 2 miles.

Accelerated services (Contd.).

LONDON AND NORTH EASTERN.		
H.	I.	J.
London-Edinburgh. Edinburgh-London. « The Coronation ».	London to Edinburgh. Edinburgh to London.	Edinburgh-Glasgow. Glasgow-Edinburgh.
High speed.	Express.	Express.
Steam.	Steam.	Steam.
Via York and Newcastle.	Via York and Newcastle.	Via Falkirk.
392 3/4 miles.	392 3/4 miles.	47 1/4 miles.
Nil.	Nil.	Nil.
2	2	4
Bogie vestibule articulated.	Bogie vestibule and articulated restaurant cars.	Bogie vestibule.
312 tons Summer. 278 tons Winter.	405 tons northbound. 371 tons southbound.	300 tons.
6 hours, both directions.	...	...
Average speed excluding station stops of 66.59 m. p. h. northbound and 66.03 m. p. h. southbound. Maximum permissible speed 90 m.p.h.	Average speed, excluding station stops, of : 55.2 m. p. h. Winter } North- 56.12 m. p. h. Summer } bound. 55.59 m. p. h. Winter } South- 56.12 m. p. h. Summer } bound. Maximum permissible speed 90 m.p.h.	Average speed, excluding station stops, of : 46.89 m. p. h. to Glas- gow; 48.91 m. p. h. from Glasgow. Maximum permissible speed 70 m.p.h.
<i>Northbound.</i> Easy. 335 1/4 miles. Moderate 52 1/2 miles. Heavy 5 miles. <i>Southbound.</i> Easy. 347 3/4 miles. Moderate 36 1/2 miles. Heavy 8 1/2 miles.		<i>Edinburgh to Glasgow.</i> Easy. 45 3/4 miles. Heavy 1 1/2 miles. <i>Glasgow to Edinburgh.</i> Easy. 47 1/4 miles.

TABLE 2. — Typical examples

ADMINISTRATION.		
EXAMPLE.	K.	L.
<i>Service</i>	London-Southampton. Southampton-London.	London-Bournemouth. Bournemouth-London.
<i>Type of train</i>	Non-stop express and semi-express with 3 stops.	Non-stop express, express with 0 stop, semi-express 7 or 8 stops.
<i>Method of traction</i>	Steam.	Steam.
<i>Route</i>	Via Basingstoke.	Via Basingstoke.
<i>Route mileage</i>	79 miles.	108 miles.
<i>Mileage of single line worked over.</i>	Nil.	Nil.
<i>Daily number of similar services.</i>	8 express. 12 semi-express.	2 non-stop express. 6 express. 12 semi-express.
<i>Type of rolling stock</i>	Standard corridor stock.	Standard corridor stock.
<i>Weight of the trains (Tare, long tons).</i>	Express, 450 tons. Semi-express, 400 tons.	Non-stop express, 365 tons. Express and semi-express, 400 tons, which can be increased by 50 tons by special arrangement.
<i>Overall journey time</i> . . . . .	...	...
<i>Speed.</i>	Average overall speeds : To Southampton. Express, 54.62 m. p. h. Semi-express, 45.27 m. p. h. Semi-express (excl. station allow- ance), 48.0 m. p. h. From Southampton. Express, 53.41 m. p. h. Semi-express, 44.43 m. p. h. Semi-express (excl. station allow- ance), 47.54 m. p. h. 3 permanent speed restrictions.	Average overall speeds : To Bournemouth. Non-stop express, 55.87 m. p. h. Express 50.63 m. p. h. Express (excl. station allowance) 52.69 m. p. h. Semi-express, 39.52 m. p. h. Semi-express (excl. station allow- ance), 44.7 m. p. h. From Bournemouth. Non-stop express, 54.92 m. p. h. Express, 51.44 m. p. h. Express (excl. station allowance) 52.69 m. p. h. Semi-express, 39.76 m. p. h. Semi-express (excl. station allow- ance), 44.09 m. p. h. 9 permanent speed restrictions.
<i>Gradients.</i> Note. — Under 1 in 250 = « Easy ». — 1 in 250 to 1 in 150 = « Moderate ». — Over 1 in 150 = « Heavy ».	London to Southampton. Easy. 73 1/2 miles. Moderate 5 1/2 miles. Southampton to London. Easy. 79 miles.	London to Bournemouth. Easy. 98 miles. Moderate 7 miles. Heavy 3 miles. Bournemouth to London. Easy. 102 1/2 miles. Moderate 3 miles. Heavy 2 1/2 miles.

accelerated services (Contd.).

SOUTHERN.		
M.	N.	O.
London-Salisbury. Salisbury-London.	London-Exeter. Exeter-London.	London-Portsmouth Harbour. Portsmouth Harbour-London.
Non-stop express. Semi-express with 3 stops.	Express with 2 stops. Semi-express with 6 stops.	Express with 3 stops.
Steam.	Steam.	Electric multiple unit.
Via Basingstoke.	Via Basingstoke, Salisbury and Templecombe.	Via Guildford.
84 miles.	172 miles.	74 miles.
Nil.	Nil.	Nil.
5 non-stop express. 8 semi-express.	3 express. 6 semi-express.	16 express.
Standard corridor stock.	Standard corridor stock.	Electric multiple-unit corridor stock.
tons all cases. May be increased by 50 tons by special arrangement.	350 tons all cases. May be increased by 50 tons by special arrangement.	...
...
Average overall speeds : To Salisbury. Non-stop express, 57.72 m. p. h. Semi-express, 46.5 m. p. h. Semi-express (excl. station allowance), 49.23 m. p. h. From Salisbury. Non-stop express, 57.06 m. p. h. Semi-express, 49.23 m. p. h. Semi-express (excl. station allowance), 50.72 m. p. h. Permanent speed restrictions.	Average overall speeds : To Exeter. Express, 53.95 m. p. h. Express (excl. station allowance), 56.31 m. p. h. Semi-express, 47.05 m. p. h. Semi-express (excl. station allowance), 50.76 m. p. h. From Exeter. Express, 51.78 m. p. h. Express (excl. station allowance), 55.4 m. p. h. Semi-express, 47.28 m. p. h. Semi-express (excl. station allowance), 51.26 m. p. h.	Average overall speed, 46.7 m. p. h.
London to Salisbury. Easy, 75 miles. Moderate 9 miles. Salisbury to London. Easy, 74 miles. Moderate 9 miles. Heavy 1 mile.	London to Exeter. Easy, 133 1/2 miles. Moderate 14 miles. Heavy 24 1/2 miles. Exeter to London. Easy, 136 miles. Moderate 15 miles. Heavy 21 miles.	Both directions. Easy, 62 miles. Moderate 2 miles. Heavy 10 miles.

TABLE 2. — Typical examples

ADMINISTRATION.	BOMBAY, BARODA AND CENTRAL INDIA	
EXAMPLE.	P.	Q.
<i>Service</i>	Bombay-Delhi. Delhi-Bombay. « Frontier Mail ».	Bombay-Ahmedabad. Ahmedabad-Bombay. « Gujarat Mail ».
<i>Type of train</i>	Mail train. 19 stops north-bound. 18 stops south-bound.	Mail train. 10 stops.
<i>Method of traction</i>	Steam.	Steam.
<i>Route</i>	Via Baroda and Rutlam.	Via Baroda.
<i>Route mileage</i>	860 1/4 miles.	305 1/2 miles.
<i>Mileage of single line worked over.</i>	617 miles.	51 1/2 miles.
<i>Daily number of similar services.</i>	2	2
<i>Type of rolling stock</i>	Eight-wheeled bogie stock, fully vacuum braked.	Eight-wheeled bogie stock, fully vacuum braked.
<i>Weight of the trains (Tare, long tons).</i>	325 tons.	366 tons.
<i>Overall journey time</i>	Bombay-Delhi, 22 h. 55 m. Delhi-Bombay, 23 h. 15 m.	Bombay-Ahmedabad, 9 h. 20 m. Ahmedabad-Bombay, 9 h. 25 m.
<i>Speed</i>	Overall average speeds : Northbound, 37.6 m. p. h. Southbound, 37.0 m. p. h. Maximum booked speed 54 m. p. h., and maximum running speed 60 m. p. h.	Overall average speeds : Northbound, 32.7 m. p. h. Southbound, 32.4 m. p. h. Maximum booked speed 50 m. p. h. and maximum running speed 60 m. p. h.
<i>Gradients.</i> <i>Note. — Under 1 in 250 = « Easy ». — 1 in 250 to 1 in 150 = « Moderate ». — Over 1 in 150 = « Heavy ».</i>	Steepest gradient, 1 in 150.	Steepest gradient, 1 in 150.

Accelerated services (Contd.).

GREAT INDIAN PENINSULA.		
R.	S.	T.
Borivli-Virar. Virar-Borivli.	Bombay-Poona. Poona-Bombay.	Delhi-Jhansi. Jhansi-Delhi.
Suburban service. 5 intermediate stations.	Mail train. 8 stops.	Passenger.
Electric multiple unit.	Electric engine.	Steam.
...
15 1/2 miles.	119 miles.	255 miles.
Nil.	Nil.	225 miles.
31	2	...
Non-corridor. Non-articulated.	Standard vestibuled.	Ordinary non-vestibuled.
7-coach train, 360 tons. 4-coach train, 202 1/2 tons.	480 tons.	188 tons.
...	Bombay-Poona 3 h. 3 m. Poona-Bombay 3 h. 15 m.	Delhi-Jhansi 11 h. 58 m. Jhansi-Delhi 12 h. 7 m.
n. p. h. balancing speed in service.	Maximum practical speed, 60 m. p. h. Overall average speed Bombay to Poona, 38.6 m. p. h. Poona to Bombay, 36.6 m. p. h.	Maximum practical speed 40 m. p. h. Overall average speed 21 m. p. h.
...	<i>Bombay to Poona :</i> Easy. 91 miles. Moderate 5 1/2 miles. Heavy 22 1/2 miles. <i>Poona to Bombay :</i> Easy. 103 miles. Moderate 6 miles. Heavy 10 miles.	<i>Jhansi to Delhi :</i> Easy. 240 miles. Moderate 13 miles. Heavy 2 miles. <i>Delhi to Jhansi :</i> Easy. 233 miles. Moderate 14 miles. Heavy 8 miles.

TABLE 2. — Typical examples of accelerated services (Concd.)

ADMINISTRATION.	SOUTH INDIAN.	BURMA RAILWAYS.	BUENOS AIRES PACIFIC.	PENNSYLVANIA.
EXAMPLE	U.	V.	W.	X.
Service	Madras-Trivandrum. Trivandrum-Madras.	Mandalay-Rangoon. Rangoon-Mandalay.	Buenos Aires-Mendoza. Mendoza-Buenos Aires, « El Cuyano ».	New York-Washington. Washington-New York, « Congressional Limited ».
Type of train	Express (metric gauge).	Express mail.	Express day train.	Express.
Method of traction	Steam.	Steam.	Steam.	Electric engine.
Route . . . . .	...	...	...	Via Newark, Trenton, Philadelphia, Wilmington & Baltimore.
Route mileage	511 1/4 miles.	385 1/2 miles.	650 miles.	224.8 miles.
Mileage of single line worked over.	511 1/4 miles.	207 1/4 miles.	436 miles.	Nil.
Daily number of similar services.	2	4	2	28
Type of rolling stock	Standard.	Standard bogie coaching stock.	No special equipment acquired.	No. of stops, from 5 to 13 per train. Al-steel cars, 70' to 84' in length. Electric engines of 4 620 H. P.
Weight of the trains (Tare, long tons).	216 tons.	308 tons, 16 vehicles.	330 tons (limited) 7 vehicles.	Variable, 804 to 1 161 tons.
Overall journey time	16 h. 49 m.	Fastest services : Mandalay to Rangoon. 13 h. 32 m. Rangoon to Mandalay, 13 h. 40 m.	Buenos Aires to Mendoza. 15 h. 15 m. Mendoza to Buenos Aires. 14 h. 55 m.	Journey time varies from 3 h. 35 m. to 4 h. 35 m.
Speed	Maximum speed, 40 to 50 m. p. h., subject to local restrictions. Overall average speed, 30.5 m. p. h.	Overall average speed of fastest service, 28.4 m.p.h. Maximum permissible speed, 40 and 45 m. p. h.	Overall average speed to Mendoza, 42.6 m. p. h., or 46.2 m. p. h. excluding stopping time. Overall average speed from Mendoza, 43.6 m. p. h., or 47.8 m. p. h. excluding stopping time.	Authorised maximum speed, 75 m. p. h. for approx. 180 miles, and 80 m. p. h. for 45 miles. — These speeds are entirely practical. Overall average speeds of « Congressional Ltd. » 62.7 m. p. h.
Gradients. Note : Under 1 in 250 = « Easy », — 1 in 250 to 1 in 150 = « Moderate », — Over 1 in 150 = « Heavy ».	Ruling gradient 1 in 100, except in Ghat section, between Shencottah and Punalur, where it is 1 in 50.	Ruling gradient 1 in 200.	124 miles of heavy grades. Remainder of line traverses undulating country rising from sea level at Buenos Aires to 2 480 feet at Mendoza.	Practically no grades.

achieved by electrification in the direction of increasing the overall speeds of extremely heavy trains.

The information supplied by the various Administrations is tabulated in Table 3. The remainder of this section will be devoted to a description of the methods adopted.

(A) Elimination of stops.

One of the simplest methods of increasing the overall speed of a train is to reduce the number of stops it is scheduled to make. Every Administration has adopted this method in some degree.

The Pennsylvania report that stops have been eliminated to a limited extent only, an important case being the closing of Manhattan Transfer consequent on the remodelling of Newark station. Electrification has enabled overall accelerations to be attained without curtailing the service offered at intermediate stations. Where the volume of traffic is light, however, stops have been eliminated provided an alternative service is available. In some cases regular stops have been made into conditional stops.

On those railways where running speeds have not been increased the elimination of stops and the time spent over such stops is the sole means of increasing the overall speed.

(B) Reduction of time spent over stops.

This method has been applied by every Administration.

The London Midland and Scottish report that particularly at small intermediate stations has it been possible to reduce the standing time of trains. This has been due in part to a reduction in heavy traffic to be conveyed by passenger train, which formerly required considerable time for loading or necessitated the attaching of an additional special vehicle.

The London and North Eastern men-

tion that station time has been reduced by quicker handling of traffic and by reduced number of engine changes en route.

On the Egyptian State Railways it was found that the former time of three minutes allowed for stopping and starting local trains could be reduced to two minutes, and running times on seven sections of line were curtailed to a considerable extent in consequence. At first this ruling was applied only to sections where engines of increased power were employed, but in 1938 its application was made universal.

On the Bombay, Baroda and Central India the station time on the electrified section of the Bombay suburban service has been reduced compared to the former steam service.

On the mail and express services of the Burma Railways between Rangoon and Mandalay, the 15 stops taking 137 minutes in 1934 have been reduced to 14 taking 107 minutes in 1938.

Owing to the extension of the electrified territory of the Pennsylvania it has been possible to reduce station time spent at stations where formerly electric engines were replaced by steam engines and vice versa. The electrification of the complete route from New York to Washington enabled this to be done at Wilmington, and the electrification through from New York to Harrisburg enabled a similar reduction in station allowance to be made at Paoli.

The Pennsylvania report also that they have achieved a progressive reduction in shunting of passenger trains at intermediate stations with consequent reduced stopping times. This has been possible by the running of through dining cars as compared with the former practice of cutting dining cars in and out at intermediate stations. The operation of through vehicles on a combination of trains has also been reduced and shunting time eliminated thereby. When it had been the practice to charge

TABLE 3. — Principal methods used to reduce the overall running time of passenger services. (January 1934 - July 1938.)

Name of Administration.	OPERATING.			MOTIVE POWER.				ROLLING STOCK.	PERMANENT WAY.
	Elimination of stops.	Reduction of time spent at stations.	Reduction in trailing load of trains.	Reduction in point to point running times by :					
				More powerful engines.	Substitution of electric for steam traction.	Substitution of diesel for steam traction.	By obtaining greater power output from existing engines.		
GREAT BRITAIN. <i>Great Western . . .</i>	Yes.	Yes.	Generally speaking, no. Trains in examples A and B limited.	No.	No.	No.	By utilizing reserve of power.	No.	Yes.
	Yes.	Yes.	Majority of cases of fast expresses, load reduced. Applies to examples C, D, E and F.	Yes.	No.	No.	No.	No.	Yes.
	Yes.	Yes.	Some cases. Applies to examples G and H, but not examples I and J.	Yes.	Yes, in case of suburban service only. 21 miles.	No.	No.	In case of examples G, and H, yes. Not otherwise.	Yes.
	Yes.	Yes.	No.	Yes.	Yes, extensively.	No.	No.	No.	Yes.
EGYPT. <i>Egyptian State . . .</i>	No.	Yes.	...	...	...	Yes, local service.	...	...	Yes.
INDIA. <i>Bombay, Baroda and Central India.</i>	Yes, in some cases.	Yes, in some cases.	No.	Partly to a slight degree.	Yes, in cases of suburban service. 15 1/2 miles	No.	By utilizing reserve of power.	No.	Yes.
<i>Great Indian Peninsula.</i>	Yes.	Yes.	No.	No.	No.	No.	No.	No.	No.
<i>South Indian . . .</i>	Yes.	Yes.	Yes, in many cases.	No.	No.	No.	No.	No.	Yes, in some cases.
BURMA. <i>Burma Railways . . .</i>	Yes.	Yes.	No.	No.	No.	No.	Yes.	No.	Yes.
CEYLON. <i>Ceylon Government.</i>	Yes.	Yes.	No.	No.	No.	Yes, on coast line.	No.	No.	Yes.
UNITED STATES OF AMERICA. <i>Pennsylvania . . .</i>	Yes, to a limited extent.	Yes.	No.	Yes.	Yes, extensively.	No.	No.	Yes, in 2 cases.	Yes.
ARGENTINE. <i>Buenos Aires Pacific.</i>	Yes.	Yes.	Yes.	No.	No.	Yes, on coast line.	Yes.	No.	Yes.

extra fares between New York and Chicago, and New York and St. Louis, etc., on trains taking less than 28 hours, it had been necessary to operate through vehicles with the object of achieving varying time savings under the 28 hours. With the elimination of extra fares, the through vehicles became unnecessary.

(C) Reduction in weight of trains.

Reduction in weight may be of two kinds : — either a limitation of the number of vehicles which are authorised to run on a train, or the introduction of new vehicles of lighter construction with the object of reducing tare weight per seat.

The former method has been used by the Great Western, London Midland and Scottish, London and North Eastern, South Indian and Buenos Aires and Pacific Railways; the latter, in particular instances only, by the London and North Eastern, and Pennsylvania.

The Great Western state that, generally speaking, the weights of trains have not been reduced, but in the case of the high-speed train, Example A, Table 2, the weight to be hauled is restricted. The same applies to the fast express given as Example B, Table 2.

On the London Midland and Scottish, in the majority of cases, the acceleration of fast express trains has been effected by limiting the weight of the trains. In practice the tare weight of all passenger trains on this Company is restricted to conform with the class of engine provided, but the limits laid down for the accelerated trains show a reduction varying with their individual nature.

Special vehicles were constructed for the fast service, Example C, Table 2, but their individual weights were rather heavier than lighter as compared with the standard vehicles.

In Examples G and H, Table 2, the London and North Eastern have reduced

the weight of their trains and introduced new vehicles. In Example I and J, the weight has not been reduced.

The Pennsylvania first introduced light-weight vehicles in 1938 and only a relatively small proportion of their rolling stock is of this description. The introduction of light-weight vehicles was a factor in reducing the schedule of a New York-Chicago train from 16 hours 30 minutes to 16 hours, and of a New York-St. Louis train from 20 hours 50 minutes to 20 hours 35 minutes east-bound, and from 20 hours 42 minutes to 20 hours 27 minutes westbound.

(D) Reduction in running times.

(a) By the provision of more powerful locomotives.

The tendency on British railways has been to increase the available power of modern locomotives. This has proved an important factor in the acceleration of passenger services.

On the Pennsylvania, the tendency has been similar. In other parts of the world, more powerful locomotives have played little part in accelerations during the past five years.

The London Midland and Scottish have increased the average value of the tractive effort of their passenger tender engines by 8.67 % from January 1934 to December 1938, while, for passenger tank engines, the increase is 7.06 %.

The London and North Eastern have designed and built special locomotives of increased power and capable of improved performance.

The Southern have provided more powerful locomotives capable of making better speed on ascending gradients.

The Pennsylvania has designed and built a new type of steam locomotive suitable for hauling heavy trains at high speed. Larger electric engines capable of higher speeds with heavy trains have also been provided.

(b) By the substitution of electric for steam traction.

Electrification has been a factor in the execution of extensive train accelerations on the

Southern,
Pennsylvania,

and in a minor way (i. e. one short sub-urban route) on the

London and North Eastern,
Bombay, Baroda and Central India.

The Southern, using multiple-unit equipment on all services, have found it possible to save up to half an hour on runs of under a hundred miles without any curtailment of intermediate stops. Electrification has also played a considerable part in the quickening of sub-urban services over the Southern Company's network of lines south of London.

The electrification of routes in the eastern part of the Pennsylvania system is worthy of comment. In 1915 the main line service between Philadelphia and Paoli was electrified, a distance of 20 miles. Later the electrification programme was extended to cover the service between New York, Philadelphia, and south to Washington, a distance of 225 miles, and from Paoli to Harrisburg, 83 miles. Electric engines were substituted for steam engines between New York and Wilmington, and New York and Paoli, early in 1933. In March 1935 electric engines ran through from New York to Washington, and, in January 1938, between New York and Harrisburg.

Both multiple-unit equipment and electric locomotives are employed.

Accelerations have been effected by :

(1) The substitution of multiple-unit equipment for steam locomotive-hauled trains making frequent stops. The acceleration of this equipment is one m. p. h. per sec. regardless of the length

of the trains, whereas with locomotives it depended on the relation between locomotive tractive effort (including adhesion) and the train weight, and was generally lower than with multiple-unit equipment.

(2) On other locomotive-hauled trains the substitution of electric locomotives for steam locomotives of lower power has permitted higher acceleration due to higher tractive effort and to ability to maintain high tractive effort at higher speeds than was possible with steam locomotives.

(c) By the substitution of diesel for steam traction.

Diesel units have been used for the purpose of speeding up services by the

Egyptian State Railways,
Ceylon Government Railway,
Buenos Aires and Pacific Railway.

Except in the case of the Ceylon Government Railway, the diesel units have been used to speed up branch-line services only.

(d) By obtaining a greater power output from existing engines.

Under this head the Burma Railways report that running times have been reduced by obtaining a greater power output from existing engines.

The Buenos Aires Pacific state that in some instances they have increased the boiler pressure of existing engines from 175 to 200 lb. per sq. in.

The Great Western and the Bombay, Baroda and Central India state that their existing engines possessed sufficient reserve power to meet the demands of the faster schedules.

(e) Raising the maximum permissible speed.

Every Administration, with the exception of the Great Indian Peninsula, reports that this has been done. Individual replies are as follows :

Great Western. — Where practicable the maximum permissible speed has been raised. This has been rendered possible at a number of points on the route of Examples A and B, Table 2, by minor track alterations.

London Midland and Scottish. — Maximum permissible speeds have been raised at certain points, and, over lines where high speeds are run, the maximum permissible speed has been fixed at 90 m. p. h. and the track adjusted where necessary, to enable this to be done. Lower maxima are enforced where the track cannot economically be made suitable for 90 m. p. h.

London and North Eastern. — In certain instances restrictions have been eased to permit of accelerations.

Southern. — On certain parts of the line the maximum permissible speed has been raised.

Bombay, Baroda and Central India. — On metre-gauge lines the maximum permissible speed has been raised. On main lines, e. g. Delhi-Ahmedabad, from 40 to 45 m. p. h.; on branch lines, e. g. Cawnpore-Achnera, from 30 to 40 m. p. h.

South Indian. — In some cases only has the maximum permissible speed been raised.

Burma Railways. — On main lines the maximum permissible speed has been raised to 40 m. p. h. and 45 m. p. h. Speed over interlocked points has been increased to 40 m. p. h. on double line and 30 m. p. h. on single line.

Pennsylvania. — On main lines, for example : New York Division, from 70 to 75 m. p. h.; Maryland Division, from 70 to 75 m. p. h. in some territories, and 80 m. p. h. in others; portions of the Philadelphia Terminal Division, from 70 to 75 m. p. h., and 80 m. p. h.; Fort Wayne Division, from 70 to 80 m. p. h.

(f) Miscellaneous methods.

The London Midland and Scottish mention the use of half-minute timings in the schedules of local services as an aid to acceleration.

On the South Indian, mixed trains have been converted to passenger trains running at a higher speed.

On the Pennsylvania, the extensive use of mechanical stokers on steam locomotives has been a factor in increasing the overall running speeds of passenger trains.

III. — TECHNICAL CONSIDERATIONS AND COSTS INVOLVED IN OBTAINING INCREASES IN OVERALL SPEEDS OF PASSENGER SERVICES.

In common with other items pertaining to railways, it is not an easy task to determine the specific additional cost of increasing the overall speeds of passenger services. In many cases the operations of a railway are so complex and interdependent that factors outside the scope of the item whose cost it is desired should be determined influence the results obtained.

In the following matter an indication will be given of the main items which may involve increased cost due to ac-

celerations of passenger services, as brought out by the answers to the questionnaire distributed on the subject.

(A) Operating.

The main item under this head is the additional train mileage it is often necessary to run in connection with service accelerations.

Additional train mileage may be classified as follows :

(a) Additional train mileage consequent upon increased traffic.

(b) Additional train mileage of new fast or high-speed trains run extra to the previous normal services.

(c) Additional train mileage necessary to compensate for stops eliminated from trains which have been accelerated.

(d) Additional train mileage due to duplication of trains as a result of the necessity of reducing the weight of trains to be accelerated.

Of the above (b), (c) and (d) can be debited to service accelerations; (a) cannot. However, the circumstances necessitating (a) are often combined with (b), (c) and (d), and thus no exact account can be determined. As a rule acceleration itself creates additional traffic and further complicates the issue.

Passenger service accelerations on British railways have been found to necessitate additional mileage under both (c) and (d). Mileage under (b) has also been incurred by the services shown in the table hereafter.

Administrations other than those in Great Britain have not found that service accelerations required the running of additional mileage.

The London Midland and Scottish under this head report that there have been certain instances where schemes for accelerating services have resulted in additional train mileage as a direct consequence of the splitting of trains into smaller units capable of higher overall speeds. In Example C, Table 2, the introduction of 803 new train-miles at a fast speed necessitated 175 additional train-miles per day. In Example D, Table 2, the acceleration of two of the services quoted necessitated 310 additional train-miles per day, while in Example F, 158 additional train-miles daily were necessary.

(B) Motive power.

(a) Alterations to locomotive design.

The demand for increased speed has led to several changes in locomotive de-

Administration.	Name of service.	Running between	Daily additional mileage.
<i>Great Western</i>	« Bristolian ».	London and Bristol.	236
<i>London Midland and Scottish.</i>	« Coronation Scot ».	London and Glasgow.	803
<i>London and North Eastern.</i> .	« Silver Jubilee ».	London and Newcastle.	536 1/2
Do.	« Coronation ».	London and Edinburgh.	785 1/2
Do.	« West Riding Ltd ».	London and Bradford.	392 1/2

The Southern in England has increased its train mileage, but this increase cannot be debited to acceleration of services. Wherever Southern lines have been electrified, the resultant service has been more frequent and quicker than formerly. The added frequency has been prompted by the desire to create traffic by attractive facilities rather than by the exigencies of service acceleration.

sign, certain of which have been reported by the various Administrations.

London Midland and Scottish. — No locomotives have been altered specially to fit them for very high speeds. New locomotives specially constructed for accelerated services have been fitted with slightly larger driving wheels, otherwise alteration in detail has followed normal development. Needle bearings have been fitted to motion pins with a view to

giving greater life and less maintenance, but they also to some extent reduce rolling resistances and improve overall mechanical efficiency.

London and North Eastern. — A new design of steam locomotive has been built with special features as follows :

Streamlining employed.

Boiler pressure increased from 220 lb./sq. in. to 250 lb./sq. in.

Ample steam and exhaust passages.

Diameter of piston valves increased from 8" to 9".

Pennsylvania. — As a result of steam locomotives being forced harder to meet faster schedules, attention was attracted to the limitations of the standard heavy passenger type locomotives employed by the Pennsylvania. One of these locomotives, 4-6-2 *Pacific* type, was placed on the Pennsylvania test plant at Altoona and extensive studies made of the superheater, exhaust nozzle (blast pipe), grates, main valves, valve setting, and pressures.

Based upon the results of these tests the following changes are being made on existing locomotives of the type under consideration, as they go through the works for heavy repairs :

1. Free air opening in table grates increased from about 11 % to about 22 %.

2. Single-pass units used in superheater instead of double-pass units with the object of reducing the pressure drop through the superheater.

The most marked improvement in locomotive performance was obtained by this method. At the highest rate of working the locomotive, the total pressure loss between boiler and steam chest was reduced to about one half its former value, and the pressure drop through the superheater elements to about one third the former value. The average steam chest pressure was increased 10 %. At the same speed and cut-off, the mean effective pressure was increased from 2 % to 15 %. At steam consumption rates in

excess of 60 000 pounds per hour the increase in indicated horse-power reached a maximum of approximately 5 %. The difference in temperature of the superheated steam at all rates of working was very small.

3. Exhaust clearance of piston valves increased with a view to steam economy in cylinders.

4. Area of six-point exhaust nozzle (blast pipe) increased in order to reduce cylinder back pressure.

In the design of their class S. 1 (6-4-4-6) Pennsylvania type locomotive, the Pennsylvania have made provision for high speed by limiting the number of pairs of driving wheels in one driving group, thus eliminating the frequent trouble experienced on high-speed locomotives where three or more pairs of driving wheels were driven from one pair of cylinders. In the S. 1 locomotive there are four cylinders, two cylinders driving the front group of driving wheels and two cylinders driving the back group of driving wheels. In this type of locomotive, which is especially intended for hauling heavy passenger trains at high speed, the diameter of driving wheels has been made 84 inches.

In the design of present Pennsylvania passenger electric locomotives the operating speed was decided upon before the design was made. No changes in the design to provide for high speeds have therefore been made. However, some of the electric locomotives, which were originally intended for high-speed service, have been placed in freight service, and this has required a change in the gear ratio of the locomotives to suit freight train speeds.

The changes which are referred to as being made to existing 4-6-2 heavy passenger locomotives will entail the following approximate cost per locomotive :

Change in grates to increase the free air opening — about \$ 175.00 per locomotive, or about 0.38 % of the average cost of the locomotive.

Application of single-pass superheaters instead of double-pass superheaters — about \$ 1 400.00 per locomotive, or about 3.11 % of the average cost of the locomotive.

Modification of piston valves to increase the exhaust clearance — about \$ 75.00 per locomotive, or about 0.18 % of the average cost of the locomotive.

Reducing cylinder back pressure by

cleaner and a general clean appearance is more easily maintained.

The London and North Eastern report that wind tunnel tests of the streamlining adopted for that Company's newly designed high-speed *Pacific* type locomotives show that the horse-power required to overcome head-on air resistance has been reduced by the amounts shewn in the following table.

Speed, m. p. h.		60	70	80	90	100
Horse-power required to overcome head-on air resistance.	Unstreamlined type.	97.21	154.26	230.51	328.49	450.92
	Streamlined type.	56.39	89.41	133.61	190.40	261.36
Horse-power saved by streamlining . .		40.82	64.85	96.90	138.09	189.56

Speed, m. p. h.		110	120	130	140	150
Horse-power required to overcome head-on air resistance.	Unstreamlined type.	599.39	778.65	988.95	1 235.87	1 520.80
	Streamlined type.	347.41	451.32	573.21	716.32	881.48
Horse-power saved by streamlining . .		252.98	327.33	415.74	519.55	639.32

increasing the area of six-point exhaust nozzles — about \$ 50.00 per locomotive — or about 0.13 % of the average cost of the locomotive.

(b) Use of streamlining.

The following Administrations which have made trials with streamlining report no practical advantages :

Great Western,
Pennsylvania.

The London Midland and Scottish report that streamlined locomotives have an advantage in that outside motion is

The horse-power saved at the various speeds shewn is thus available for increasing the speed and acceleration of trains.

Dynamometer car experiments with the « Silver Jubilee » train, Example G, Table 2, shew that, whilst only about 400 drawbar horse-power is required on the level, the average drawbar horse-power required on the run from London to Newcastle is 620. To this must be added the horse-power required to overcome the internal resistance plus the head-on air resistance of the locomotive which with an unstreamlined engine at

80 m. p. h. is about 450 horse-power, but with a streamlined engine is reduced to 330 horse-power. The saving in power output due to streamlining is therefore in the region of 10 %.

The coal consumption of the engines working the « Silver Jubilee » train of 248 tons behind the tender averages 39 lb. per train-mile. If the consumption of coal is proportionate to the power, the saving due to streamlining would be about 4 lb. per train mile.

The Administrations agree that streamlining offers disadvantages in regard to maintenance but that the provision of adequate access doors tends to reduce inaccessibility.

(c) Effect of acceleration on maintenance costs.

The Administrations were asked to state what had been the effect of passenger train accelerations on locomotive maintenance costs. Individual answers are as follows :

Great Western. — No noticeable effect to date.

London Midland and Scottish. — Provided that in the case of the accelerated services, the loads are reduced so that the overall work performed by the locomotives is not increased, it is anticipated that there will be no additional locomotive maintenance costs, apart from increased mileage run.

London and North Eastern. — The maintenance costs have been slightly increased.

Southern. — Not ascertainable.

Bombay, Baroda and Central India. — Practically nil.

Great Indian Peninsula. — No increase.

South Indian. — Acceleration has necessitated more rigid and frequent inspection of locomotive parts.

Ceylon Government. — No visible effect yet.

Burma Railways. — Not ascertainable.

Buenos Aires and Pacific. — It is anticipated that repair costs will be slightly increased.

Pennsylvania. — It is our considered judgment that maintenance costs have not been adversely affected.

The substitution of mechanical lubricators for hydrostatic lubricators, pressure grease lubrication for gravity grease lubrication, has been accomplished along with the increase in locomotive speed. These improvements have reduced bearing troubles.

(d) Increasing the power output of existing locomotives.

Only one Administration has replied regarding the cost incurred in obtaining a greater power output from existing engines.

The Burma Railways submit the following interesting particulars :

EURMA RAILWAYS. — Result of acceleration upon evaporation and combustion.

—	Before acceleration, 1934.	After acceleration, 1938.
Evaporation per sq. foot of total heating surface (lb. of water per sq. foot per hour)	3.8	4.2
Coal consumed (lb. per train-mile) . .	39	37
Coal consumed per run (lb.)	15 034	14 263
Time for the run . .	15 h. 10 m.	13 h. 40 m.
Grate area of engine (sq. feet)	31	31
Coal burnt per hour (lb.)	991	1 044
Coal burnt per hour per sq. foot of grate area (lb.)	31.9	33.6

Acceleration of the service in this case has resulted in a reduction in the amount of fuel consumed per mile. Similar results should be expected where the reduction in the overall time the engine is in steam is appreciable.

(C) Rolling stock.

(a) Use of streamlining.

Little has been done by the Administrations in the direction of streamlining coaching stock.

The London and North Eastern report that, whilst no data is available on the effect on the speed and acceleration of trains due to the coaches being streamlined, results obtained with the dynamometer car on the « Silver Jubilee », Example G, Table 2, indicate that the train resistance is substantially reduced, but this cannot be determined accurately until further trials have been completed.

(b) Effect of acceleration on maintenance costs.

In regard to whether an increase in maintenance costs of rolling stock resulted from acceleration of services, the following replies were received :

Great Western. — No noticeable effect to date.

London Midland and Scottish. — In the case of new high-speed services with limited accommodation, the maintenance cost of the coaching stock is increased owing to greater attention being given to maintaining good riding. This involves more frequent attention to lubrication and adjustment and shorter mileages between repairs.

On normal services which have been accelerated there will be some increase in maintenance costs, the extent of which has not yet been determined.

London and North Eastern. — Train accelerations have resulted in a slight increase in coaching stock maintenance costs.

Southern. — Not ascertainable.

Bombay, Baroda and Central India. — Practically nil.

Great Indian Peninsula. — No data yet available.

South Indian. — On the whole, trivial.

Ceylon Government. — The higher speeds have not been in force long enough to give definite figures, but at present no appreciable difference is noticed.

Burma Railways. — No appreciable effect on annual coaching stock maintenance costs. The rolling stock concerned in the accelerated main-line services is heavy repaired annually as was done before the acceleration and the same amount is done on it as was done formerly.

Buenos Aires and Pacific. — Coaching stock for high-speed services requires increased attention. Separate detail costs not available.

Pennsylvania. — No specific data available. High train speeds result in increased brake shoe wear, slid flat wheels and thermal heat cracks in wheels. Increased breakage of windows due to suction of passing trains has been experienced and this is being corrected by the application of metal window sashes and shatter-proof glass. It is also necessary to keep the treads of wheels in more perfect condition to preserve good riding qualities at high speeds.

From these replies it is possible to conclude that, where the general level of speed is high, acceleration will entail some extra maintenance cost for the rolling stock, but that where the general level of speed is relatively low considerable acceleration is possible without any such increase.

(D) Braking systems.

On those systems where a high stan-

dard of speed is combined with a relatively dense traffic, considerable attention has recently been paid to improving the efficiency of braking equipment.

Thus in Great Britain, where the automatic vacuum brake is in use, experiments have been made with direct acting valves with the object of reducing delay in brake application.

The London Midland and Scottish state that acceleration of steam trains has emphasised the desirability of more efficient braking. Direct acting valves have been applied to the standard automatic vacuum brake,* and detail improvements have been effected in brake mechanisms. Trials are being made with brake gear applying an increased pressure at high speeds; also with non-metallic brake blocks having a higher co-efficient of friction than cast iron.

With direct acting valves applied to the automatic vacuum brake a train composed of a 162-ton 4-6-2 locomotive and 14 coaches, total weight of engine and train 550 tons, gave the following stopping distances on level track :

From 90 m.p.h. to stand in 1490 yards.
From 75 m.p.h. to stand in 1010 yards.
From 60 m.p.h. to stand in 635 yards.

The London and North Eastern have increased the brake percentages on locomotives and carriages. Experiments are being made with direct acting valves.

The Southern are experimenting with rapid acting air admission valves on vacuum brake cylinders.

In the United States the introduction of light-weight passenger vehicles and the increase in passenger train speeds has resulted in the subject of shorter stopping distances being investigated by the American Association of Railroads.

The Pennsylvania report that present conventional trains have a braking ratio of 90 % for service braking and 150 % for emergency braking. The stopping distance from 60 m. p. h. with an emer-

gency brake application is approximately 300 yards.

The type UC brake equipment now on conventional passenger vehicles has been standard since 1913, but has been superseded by the D-22-A control valve for new light-weight vehicles. This new D-22-A control valve equipment will develop a braking ratio of 150 % with 60 lb. per sq. inch brake cylinder pressure and can be conveniently increased to a maximum of 250 % by increasing the brake cylinder pressure up to 100 lb. per sq. inch. This can be accomplished without any change in the present standard 110 lb. per sq. inch. brake pipe pressure.

The cost of the new brake equipments described above and of the experiments in connection therewith must be debited to the increase in passenger train speeds.

(E) Signalling.

Where the general level of speed is high, various modifications have been found necessary in signalling arrangements.

(a) *Alteration in position of fixed signals.*

The following Administrations have found it necessary to reposition certain signals :

Great Western,
London Midland and Scottish,
London and North Eastern,
Great Indian Peninsula,
Pennsylvania.

The Great Western have altered the position of distant signals in some cases.

The London Midland and Scottish have altered the positions of distant signals in conjunction with their signal replacement programme. The cost per signal varies according to local conditions and whether semaphore or colour

light signals are employed. Where a semaphore distant signal is replaced by a semaphore signal at a greater distance from the home or stop signal the usual replacement cost is increased by £ 10. Where a semaphore distant is replaced by a colour light distant at a greater distance from the home or stop signal, the usual replacement cost of a semaphore by a semaphore is increased by £ 200. These are average costs based upon actual cases carried out.

The London and North Eastern have repositioned distant signals at an average cost of £ 121 per signal. Over part of the route traversed by high speed trains the cost per mile of single track was £ 73.

On the Great Indian Peninsula it has been necessary on fast running sections to move a number of warner (distant) signals further out in order to give increased braking distances. The cost has been approximately 100 Rupees (£ 7.10.0 d.) per station.

On the Pennsylvania, anticipating fast services, signal spacing has been and will be increased, generally by removing every other signal, and in some cases by altering the position of signals. The cost in electrified territory is \$ 400 per track mile, and outside electrified territory \$ 200 per track mile.

(b) Other signalling alterations.

The London and North Eastern, on certain existing colour light signalled sections, have introduced a fourth (double yellow) aspect with the object of giving additional braking distances.

The Great Indian Peninsula, on fast running sections have found it necessary to change the mode of signalling from « B » class signalling to « A » class signalling, i. e. instead of using the outer and warner as the first signal, using the warner as the first signal similar to the practice in Great Britain. This has cost 160 Rupees (£ 12) per station.

(c) Use of preliminary warning for distant signals.

The London Midland and Scottish employ banner type repeater signals in cases where the approach view of the distant signal is insufficient. The average cost of banner repeater signals is £ 80.

The London and North Eastern repeat the distant signal indication in some cases.

The Southern use a preliminary warning for distant signals but this was not adopted in connection with train accelerations.

The Pennsylvania report using a preliminary warning in some cases but they intend omitting the second distant signal as far as possible and increasing the warning distance for home signals by increasing the spacing between signals.

(d) Use of special signalling regulations.

In Great Britain the regulations for signalling by the absolute block system have been modified by certain Administrations operating fast trains.

The Great Western, London Midland and Scottish and London and North Eastern have, where necessary, laid down that permission must not be given by a signalman for certain fast trains to approach unless an extended clearance is available.

The London Midland and Scottish and London and North Eastern use a special bell signal for certain fast trains.

(e) Use of special slackening signals for permanent and temporary speed restrictions.

On the London and North Eastern, in the case of temporary speed restrictions for track repairs, the distant warning boards, normally fixed at 1/2 mile from the commencement of the work, are moved out to 1 500 yards on routes used by high-speed trains, to give additional braking distance. High-speed trains ob-

serve the same speed limits as other trains. No slackening signals are provided for permanent speed restrictions, except in a few cases, but these existed prior to the acceleration.

No administration reports the adoption of automatic devices controlling the train for the specific purpose of introducing accelerated services.

(F) Permanent way and structures.

1. Improvements preparatory to the introduction of high-speed trains or substantially accelerated services.

Any work carried out by the various Administrations to prepare the line for higher speeds falls under the following headings :

(a) Improvement of the roadbed, ballasting and drainage;

(b) Renewal and strengthening of the permanent way;

(c) Adjustment of curves, and remodelling of junctions and connections;

(d) Renewal or strengthening of bridges.

(a) Roadbed, ballasting and drainage.

Good drainage of the roadbed and ballast plays an important part in maintaining the stability of the permanent way. It demands constant attention on any line which already carries fast traffic, and consequently on such lines there was relatively little improvement needed in this direction prior to the introduction of accelerated services.

The Great Western, however, found it necessary to do a substantial amount of drainage work and reballasting prior to the inauguration of their accelerated services on the Paddington-Bristol route, Example A, Table 2.

The Pennsylvania also carried out some improvement of the roadbed and intensified their ballast tamping operations.

The Ceylon Government Railway

carried out a general betterment of ballasting and drainage prior to acceleration, and are spending Rs. 300 000/— (£ 22 500) in ballasting on the Coast line between Colombo and Matara (99 miles).

(b) *Renewal and strengthening of the permanent way.*

Extensive renewals and re-sleepering were carried out by the Southern on four of the principal routes. In certain cases additional sleepers were provided.

The Great Western also carried out a substantial amount of relaying before the introduction of faster services.

On the Pennsylvania heavier rail was installed.

(c) *Adjustment of curves; and remodelling of junctions and connections.*

The bulk of the work required to prepare the line for faster services comes under the heading of adjustment of curves. Most Administrations undertook a considerable amount of curve adjustment, comprising realignment, increase or modification of superelevation, and improvement of transition curves.

The average cost of such improvements is quoted by three companies, as follows :

Great Western :—

80 miles of curved track dealt with
at an average cost per mile of . . . £ 50

London Midland & Scottish :—

Improvement of the Coronation Scot
route (Euston-Glasgow), at an average
cost per mile of track dealt with
of £ 86

Burma Railways :—

Curve adjustment on the Rangoon-
Mandalay line (386 miles) was completed
at a cost of . . . Rs. 12 300/- (£ 922)
i. e. an average cost per mile of the
whole route of Rs. . . 31.9/- (£ 2.80 d.).

Apart from the general improvement of curves, major alterations have been made in some cases, notably on the Southern, where realignment necessitated a new formation in one instance, and in another the construction of a fly-over line to enable local trains to be kept clear of the fast running lines, while the layout of tracks at several stations had to be completely remodelled to facilitate the passage of fast trains. No information as to the cost of these particular works is available.

In contrast with the relatively small costs quoted above for improvements mainly on open line, the London and North Eastern quote three examples of improvements made at or near stations where the costs per mile of single track were £ 690, £ 320 and £ 4 307 respectively. These three cases, particulars of which are tabulated below, show the great expense involved in making a substantial improvement of curvature to provide for appreciably higher speeds where the conditions are complicated at or near stations.

involve the use of heavier locomotives, it is natural that such heavier loading will in some cases necessitate the earlier renewal of certain bridges, though not necessarily prior to the introduction of higher speeds. This is reflected in the maintenance of the bridges and is dealt with under that section.

2. The effect of higher speeds on maintenance.

The effect of increased speed is chiefly noticeable in greater liability of track to get out of line, and comfortable running alone demands a high standard in the matter of detailed levels. Higher speed involves particular attention to the condition of points and crossings and to weak places in the track formation.

The need for increased maintenance has been felt on the Southern, Pennsylvania, and Ceylon Government Railway. The Southern is meeting this demand by the introduction of improved processes and appliances.

On other Administrations the effect of

Case No.	Radius (chains)		Permissible speed, (m. p. h.)		Length of single track (miles).	Cost per mile of single track.
	Before improvement.	After improvement.	Before improvement.	After improvement.		
1 down up	Max. 55	Max. 233	70	80	0.9	£ 690
	Min. 621	Min. 133 305				
2	365 45	233 50	60	70	1.72	£ 320
3	200 38	170 55	55	70	0.75	£ 4 307

Each case was at or near stations.

(d) *Renewal or strengthening of bridges.*

The Pennsylvania is the only Administration which reports that it was necessary to strengthen bridges prior to the introduction of accelerated services. No particulars are given.

As high speeds on some routes may

increased speed has not so far been appreciable.

Such effects as have been noticed, the means employed to cope with them, and the costs, so far as they are ascertainable, are given below :

(a) *Maintenance and inspection staff.*

The number of men employed to maintain the track is clearly dependent

to some extent on the density and speed of traffic, but unless one or the other of these factors is very substantially increased, an increase in the maintenance staff has not been found to be warranted.

In the experience of the four Administrations in Great Britain no increase in maintenance staff has yet been necessitated by higher speeds. The frequency of day-to-day inspection of the track, and the number of men employed for this purpose have likewise been unaffected by the increase in speeds.

The need is felt, however, on the London and North Eastern, for more effective supervision of the maintenance staff, and the appointment of a Senior Permanent Way Inspector has been made on one District, and a similar appointment for another District is under consideration. A further consequence of high speeds is the occasional need for intermediate look-out men for purposes of protection and additional men have been engaged accordingly.

The Pennsylvania reports that an augmented maintenance force and more frequent inspections have been necessitated, but no particulars are furnished.

The Great Indian Peninsula is the only other Administration which has found it necessary to insist on more frequent inspection of the track, and this is done by the existing staff.

No change in the supervision or protection of level crossings has been necessitated by higher speeds.

(b) *Consumption of material for maintenance purposes.*

An increased demand for material is noticeable on the London and North Eastern and the Pennsylvania, while on the London, Midland and Scottish more ballast has been required in some cases to provide a greater depth below the sleepers.

On other Administrations there has been no noticeable increase in the quantity of material consumed.

Renewals have been anticipated by one or two years in certain cases in consequence of acceleration of services on the London and North Eastern. This has resulted in an increased annual mileage renewed.

The Ceylon Government Railway reports that corrugation of rail surface is on the increase, due possibly to more severe braking.

(c) *Improved processes and appliances.*

The need for greater accuracy in the maintenance of track for high speeds to ensure smooth and comfortable running has given rise on most Administrations to better methods of packing, and to the consideration of the reduction in number of rail joints. The process known as *measured shovel packing* has been introduced by the Southern, London and North Eastern and London, Midland and Scottish, rather as a matter of normal advance in the use of modern processes than as a step necessitated by higher speeds.

The Southern has made extensive experiments in the welding of rails to eliminate joints. They have also extended the use of rail and flange lubricators to minimise the side wear of rails. More directly as a result of higher speeds they have increased the use of spring crossings, and have undertaken the more frequent reconditioning of worn crossings by welding.

(d) *Bridges.*

The renewal of superstructures of some underline bridges has been accelerated on the London and North Eastern, and the effect of greater weight and higher speeds allowed for.

Increased maintenance has been required on the Pennsylvania and the

Southern, but no other Administrations report increased maintenance of bridges due to higher speeds.

(e) *Increased cost of maintenance of permanent way and structures.*

There has been an increase in the total annual cost of upkeep per single mile of track on the London and North Eastern since the accelerated services started, but no reliable cost on account of accelerated services can be given at this stage.

The Pennsylvania reports that cost factors have been so involved with other factors that direct increases due to higher speeds are not available.

Other Administrations report no appreciable increase in maintenance costs.

3. *The effect of higher speeds on the design of permanent way.*

Anticipation or experience of higher speeds may be expected to influence the design of permanent way in two respects :

(a) by demanding a stronger type of permanent way, involving the use of

heavier rails,
stronger fastenings,
closer sleepering,
deeper or wider ballast;

(b) by necessitating improved design of switches and junctions to allow of higher speeds over them.

(a) Three Administrations have found the use of heavier rails necessary, viz., the Southern, the London and North Eastern, and the Pennsylvania. The first two have adopted rails of 100 lb. per yard at certain places where traffic is dense, in lieu of the usual 95-lb. section.

Stronger fastenings have been adopted by the Pennsylvania, while the Southern have introduced through bolts in lieu of screws or spikes in conjunc-

tion with chairs having serrated bases, with a view to providing increased resistance to outward thrust. Through bolts have similarly been experimented with on a large scale on the London and North Eastern, but the final design of chair comprising improved features to resist outward thrust is still under consideration.

The Great Western have had through bolts and serrated chairs, similar to those referred to above, in general use for some years and have not had to consider any stronger means of fastening in view of higher speeds.

Sleeper spacing has been made closer on the Southern, and joint sleepers two inches wider have been adopted, while the London and North Eastern are making tests with one or two additional sleepers per 60-ft. rail length. No altered conditions in regard to sleepering are reported by other administrations.

A greater depth of ballast has been provided in some cases on the London, Midland and Scottish and London and North Eastern with a view to better distribution of load on the formation, and improved drainage. The Pennsylvania has increased the width of ballast across the track to provide greater lateral stability.

The only costs quoted are those for heavier rail and additional sleepers as used to some extent on the London and North Eastern. The increased cost of using 100-lb. instead of 95-lb. rails is £ 77 per mile of single track. The provision of two additional sleepers per 60-ft. rail length (giving a total of 26 sleepers per length) represents an increased cost of £ 141 per mile of single track.

(b) In order to permit higher speeds at junctions, large radius switches, or specially long switches, have been adopted by several Administrations. The types in use and the corresponding radii and speeds allowed are tabulated below:

Railway Company.	Type and length of switch.	Radius of curve, chains.	Speed, m.p.h.	Remarks.
<i>Pennsylvania . . .</i>	Straight. 45 ft.	52 30	35 30	No superelevation provided.
<i>Southern</i>	Semi-curved « E » » « F »	37 57	40	Superelevation has been provided and higher speeds allowed in a few cases of single connections or cross-overs where « two level chairs » have been used.
<i>London Midland and Scottish.</i>	Semi-curved « E » » « F »	37 58	40 50	Where it is necessary to use a turnout or lead curve sharper than the switch curve « two level chairs » are introduced to maintain the permissible speed determined by the type of switches employed.
<i>London and North Eastern.</i>	Semi-curved « E »	37	...	No superelevation usually provided.
<i>Great Western . . .</i>	Straight. 30 ft.	...	...	Used in the case of one junction only. 1 1/2" superelevation was provided on the curve by adzing timbers.

The practice on the London, Midland and Scottish, when switches are situated on curves, is as follows : The switches are generally laid level at the toe, where two tracks of equal importance diverge. If a higher speed is desired over one track the switches are canted at the toe to suit the higher speed, but not to an extent that will create a greater cant deficiency than 2 3/8" (or occasionally 3") for the other track. On curves of similar flexure the layout is canted to suit the faster track but so as not to introduce an excess of cant on the slower track of more than 1 1/2" or a deficiency of cant of more than 2 3/8" in ordinary circumstances.

The Ceylon Government Railway has been able to permit higher speeds

through facing points at certain stations by installing up-to-date bolt locking of the points.

4. Stresses in track under high speeds, and rules for permissible speed on curves in relation to radius and superelevation.

A knowledge of the stresses set up in straight and curved track under high speeds would be of value for permanent way design. The only Administration which has attempted to determine these stresses is the Pennsylvania, and this has been done by magnetic strain gauges. No conclusions have been come to which would enable rules to be formulated on this basis.

The rules employed by the various Administrations for determining the

highest speed permissible on curves in relation to curvature and superelevation are set out below. For better comparison the effect of these rules for the case of 6" superelevation is illustrated graphically in figure 1. This graph illustrates the practice on the British and Pennsylvanian Railways.

Great Western. — Superelevation, where possible, is made 7/8ths of that theoretically required for the speed and curvature, but in difficult cases maxi-

a limiting speed of 75 m. p. h. This corresponds closely with a superelevation deficiency of 15 per cent. below the full theoretical amount obtained by the formula, $S = \frac{.06 V^2}{R}$

$$S = \frac{.06 V^2}{R}$$

(S in inches, V in m. p. h., R in chains).

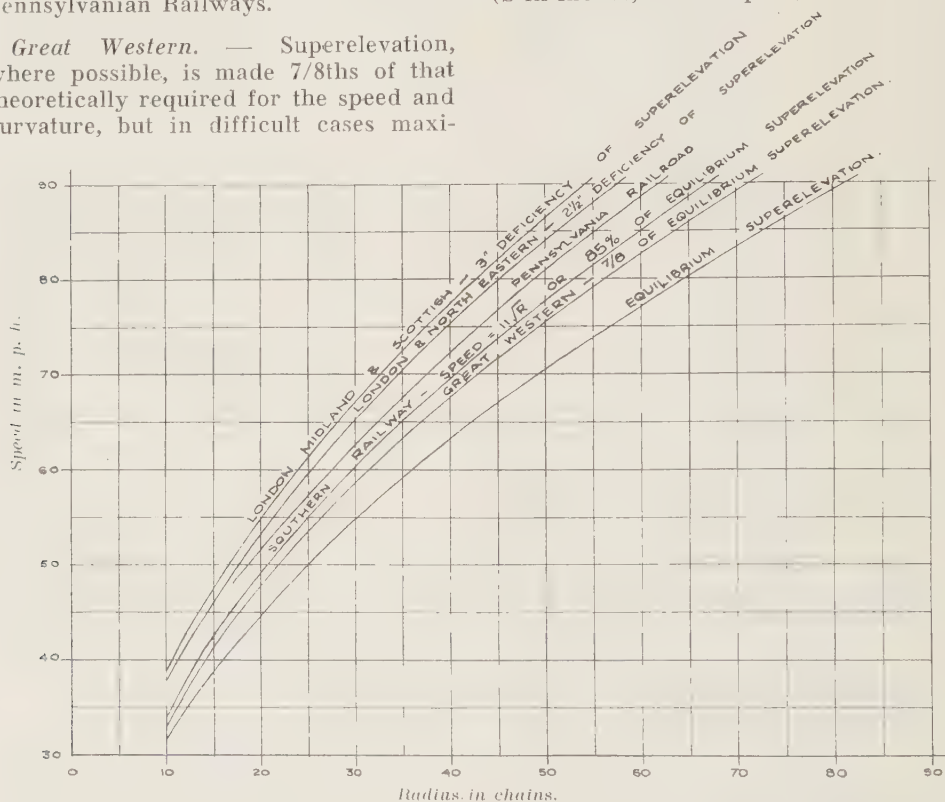


Fig. 1. — Comparison of rules for maximum permissible speed on curves of 4' 8 1/2" gauge, with 6" superelevation.

imum speeds may be based on a cant deficiency of about 2 1/2 inches.

The cant gradients used are :

for speeds up to 50 m.p.h. . . . 1 in 792
for speeds 50 to 65 m.p.h. . . . 1 in 1080
for speeds over 65 m.p.h. . . . 1 in 1440

Southern. — For curves suitably transitioned and superelevated, a maximum speed, $V = 11 \sqrt{R}$, is permitted up to

The cant gradient desirable for high speed is 1 inch in 100 ft. (1 in 1200), but frequently this has to be increased to a maximum of 1 inch in 66 ft. (1 in 792) where the length available for the transition is limited.

London Midland and Scottish. — The usual deficiency of superelevation adopted for high-speed running is that

a speed of 10 per cent. in excess of (a) a speed restriction, or (b) the highest average speed, shall not give a deficiency of more than 3". The maximum superelevation is 6", and cant gradients vary between 1 in 360 to 1 in 720 for speeds between 50 and 90 m.p.h. Should the radius of a curve and its superelevation not allow an unlimited speed, a speed restriction would be imposed approximately 10 per cent. less than the speed causing a 3" deficiency.

London and North Eastern. — Normally full equilibrium superelevation is provided. The cant gradient is limited to 1 1/2" per second, and the rate of increase of unbalanced radial acceleration must not exceed 1 ft. per second per second in a second. Variation from the standard superelevation amounting to a deficiency of 2 1/2" is normally allowed, and in certain cases deficiencies up to 4 3/4" have been adopted.

Pennsylvania. — The permissible speed in relation to radius and superelevation is based on a table from which the graph for 6" superelevation in figure 1 has been compiled. A speed 10 per cent. in excess of that laid down is not considered hazardous.

Ceylon Government Railway. — Equilibrium superelevation is provided for the permissible speed which ranges from $6.7 \sqrt{R}$ to $8 \sqrt{R}$. These rules may be altered to suit local conditions.

Bombay, Baroda and Central India. — Broad gauge. — Equilibrium superelevation for an average speed of 45 m.p.h. is provided. Cant gradient, 1 inch in 50 ft. (1 in 600). The maximum speed attained is 60 m.p.h. Check rails are provided for curves sharper than 4°, or when full superelevation cannot be given.

Metre gauge. — 75 % of equilibrium superelevation is provided, with maximum of 4". The maximum speed, $V = 1.25 \sqrt{R}$ (R, radius in feet), subject to local limitations. The cant gradient varies from 1 inch in 66 feet to 1 inch in 100 ft. (1 in 792 to 1 200), and where this cant gradient is not possible speed is limited.

Great Indian Peninsula. — Equilibrium superelevation for a speed of 45 m.p.h. is provided, and permissible speed, $V = 1.35 \sqrt{R-220}$ (V in m. p. h., R in feet). The cant gradient is 1 inch in 60 feet (1 in 720).

IV. — EFFECT OF INCREASED SPEED OF PASSENGER SERVICES ON OPERATION.

The greater the disparity in speed between the fastest and slowest class of train using a line of railway, the more will the capacity of that line be reduced. This is axiomatic, and has as a corollary that the capacity of a line is increased if the speeds of different classes of trains are as nearly uniform as possible.

It is to be expected, therefore, that the acceleration of passenger trains, and, particularly the operation of high-speed trains, would reduce line capacity unless steps were taken to achieve a ge-

neral compensating increase in speed of all classes of trains.

Individual answers to this question are as follows :

Great Western. — Acceleration of passenger trains has necessitated only a slight retiming of certain local services. No cancellations of trains have been necessary and no general speeding up of all classes of trains has been undertaken.

London Midland and Scottish. — Passenger train accelerations have been

found to have a restrictive effect on line capacity and the timings of freight trains have had to be altered in certain cases. Active steps have been taken, and continue to be taken, in connection with the speeding up of freight services and subsidiary and local passenger services.

London and North Eastern. — No cancellations of trains have been necessary and no general speeding up of all classes of trains has been undertaken.

Southern. — The acceleration of passenger services achieved by means of electrification has been accompanied by a considerable increase in train mileage with a view to giving improved facilities. As a result, paths for freight services have been curtailed, chiefly on electrified lines.

To a limited extent the time table has been re-organised with the object of increasing freight traffic during the night. On certain sections of the line owing to

the density of passenger traffic the working of freight train traffic to and from some of the principal depots has to be confined to the period midnight to 5.0 am. when electric trains are not running.

No other Administration reports any difficulty under this head.

A summary answer to the question is that on two railways in Great Britain certain difficulties in train timing have been experienced as a result of accelerations but that no other Administrations have suffered likewise beyond having to make a few minor alterations in their time tables.

Where the traffic density is low or where a modern signalling system is designed to give a very high line capacity the problem of scheduling trains that run faster than the average is much simpler than where traffic is dense and a traditional form of signalling is employed.

V. — COMFORT OF PASSENGERS ON FAST AND HIGH-SPEED SERVICES.

(a) Rolling stock.

The gradual increase in running speeds of passenger services has directed considerable attention towards improving the comfort of passengers not only on high-speed services but also in other accelerated trains running at lower speeds.

The more important improvements have been made in springing and suspension, design of seating, ventilation and noise reduction.

The Great Western have improved rolling stock design and upholstery.

The London Midland and Scottish are making tests with modified tyre profiles, improved springing and suspension, and with the spraying of noise insulating material on sheets and members to reduce noise.

The London and North Eastern have introduced pressure ventilation on very fast services which has been found

greatly to enhance the comfort of passengers. Facilities have been provided whereby meals and other refreshments are available to passengers without the necessity for their moving from their seats. On the « Coronation » services, Example H, Table 2, a *beaver tail* observation car is attached to the rear ⁽¹⁾. On high speed trains bogies have been constructed with stiffer sections to withstand the higher speeds. Noise has been countered by providing sound insulation for the roofs, floors and sides of the carriage bodies. The windows have been fitted with double glass separated by rubber.

The Southern are experimenting with noise insulating materials applied to the bodies of their vehicles and with the use of double windows.

(1) See *Bulletin of the Railway Congress*, August 1937, page 1798.

The Bombay, Baroda and Central India are introducing roller bearings and special type axle boxes, the use of ferrobestos on bogie slides, and the air-conditioning of certain coaches.

On the Burma Railways, bogie swing links have been modified to improve the riding of coaches. A redistribution of bogies has been carried out to ensure only 6' 6" and 5' 6" wheel base bogies normally running on accelerated services. 5' 6" bogie frames have been strengthened. Bogie springs have been redesigned, and testing and issuing methods improved to ensure that springs on each bogie are suitably matched.

The Buenos Aires and Pacific have improved seating and ventilation, and provided shock absorbers to improve the riding of vehicles.

The Pennsylvania are directing attention to improvements in spring suspension, better selection, design and manufacturing of springs; maintenance of closer limits of wear in bogie parts, such as pedestal jaws, bolsters, centre plates, etc.; also, better maintenance and closer limits in drawgear.

(b) **Permanent way.**

All administrations have constantly in mind the demand for smooth running at speed. This entails the maintenance of

the track to a high degree of accuracy as regards alignment, and both longitudinal and cross levels. The Hallade track recording instrument is in frequent use by several of the Administrations for registering oscillations and detecting inaccuracy, thus enabling imperfections to be remedied before they develop to a serious extent.

The following Administrations are making experiments with a view to further improvement in running :

London Midland and Scottish. — Experiments are being made with 120-foot rails, butt jointed rails, and the welding of rail joints. Closer sleeper spacing is also being tried.

London and North Eastern. — Experiments with 120 ft. rails and welded rail joints.

Southern. — Closer sleeper spacing and wider sleepers at joints.

South Indian. — Experiments are being made with joint sleepers, and welded rail joints.

Bombay, Baroda and Central India. Proposals are under consideration to lay long lengths of jointless track.

Burma Railways. — To improve running through points and crossings the rail joints are being closed up.

VI. — **COMMERCIAL RESULTS OF PASSENGER TRAIN ACCELERATIONS.**

Although the information elicited on this subject is somewhat indefinite, it is clear that in almost every case the acceleration of passenger services has met with considerable success and has been appreciated by the travelling public.

The difficulty encountered by the Administrations in supplying specific information is due to the fact that receipts from passengers using the accelerated services are seldom segregated. There is also the further possibility that receipts on connecting services are influenced by such accelerations. Short

of the issue of questionnaires to travellers it is impossible to discover the reasons causing them to patronize the services by which they travel.

Where there are a number of alternative services between certain points and the services have not all been accelerated in the same degree, or a new fast or high-speed train has been introduced, there is the added possibility that the success of the faster trains, or of the new service, is gained merely at the expense of the slower ones. In such a case the railway obtains no increased reve-

nue, though it should not be forgotten that the improved services are probably a factor in retaining to the railway traffic which would otherwise have used alternative means.

The Great Western report that accelerations to passenger services have enabled departure and arrival times convenient for business purposes to be arranged at terminal points.

In the case of the London Midland and Scottish, considerable and valuable publicity has been achieved, the travelling public have been made aware of that Company's efforts to improve their services, and appreciation has been expressed by passengers.

In their reply the London Midland and Scottish continue by saying that the five years 1933-1937 have seen a steady increase in passenger traffic. There have been increases in the number of passenger journeys between certain pairs of cities between which accelerated services have been introduced, but there is no reason to suppose that such increases bear any particular relation to the speed of the railway service.

The « Coronation Scot » services, Example C, Table 2, are an instance where an additional fast train has been instituted between two large centres. The seating capacity of the train is 190, and for the first year of its operation the average loadings achieved were 76 % of capacity northbound and 73 % of capacity southbound. The institution of this additional service, however, can hardly be said to have created entirely new traffic, but rather to have subducted traffic from other services.

In the cases of Examples D, E and F, Table 2, the same general remarks apply. Passenger journeys between the cities concerned have risen over the past five years, but the incidence of the accelerations is too recent to admit the proving of the rise in traffic as resultant upon them.

On the London and North Eastern,

from a commercial point of view, the patronage afforded the accelerated services has justified their introduction, and indicates that the travelling public appreciate the reduction in journey time, particularly for long journeys. Where formerly passengers required to break their journey overnight en route, they are now able to complete their journey in the course of a day as a result of the improved services.

The London and North Eastern give the following financial results for their « Silver Jubilee » and « Coronation » services, Examples G and H respectively, Table 2.

Service.	Receipts and expenses per loaded train-mile. Four weeks ending 9th July, 1938.			
	Receipts.		Expenses (*).	
	s.	d.	s.	d.
« Silver Jubilee » . . .	15	5	2	5
« Coronation »	16	2	2	6

The Southern report that the acceleration of passenger services has undoubtedly combatted a tendency on the part of the travelling public to use other means of travel.

The South Indian report a general improvement in traffic and earnings contemporary with acceleration of services.

On the Ceylon Government Railway acceleration of services was adopted to combat bus and lorry competition, but the success achieved up to the present has not been great.

(*) The expenses quoted include locomotive and carriage expenses (including renewal, repairs, maintenance and cleaning), all train staff costs (including clothing and insurance), cost of stores and stationery, advertising expenses and commission on bookings.

Fast local shuttle services on the Burma Railways have undoubtedly proved successful in bringing back some of the passengers lost to road transport, but during the year 1938 owing to trade depression and other causes, particularly severe competition by road services, results have not been so gratifying. The acceleration of main line services has undoubtedly been appreciated.

The Buenos Aires and Pacific state that it is not possible to furnish exact details of the increases in passenger traffic and receipts as a direct result of the acceleration of passenger services in general, or through the introduction of the « El Cuyano » express trains between Buenos Aires and Mendoza, in view of the fact that, in addition to these accelerated services, reductions in

passenger fares and combinations with underground railways were established.

However, the accelerated services have definitely influenced passenger traffics in a rising direction.

Taking September, 1938, as a representative month, the Buenos Aires and Pacific report an average loading of 225 passengers per train on their « El Cuyano » expresses.

The Pennsylvania report that their quickened services have undoubtedly retained passenger traffic which might have passed by other means, but that changing business and economic conditions in the 4-year period, 1934 to 1938, have affected the volume of passenger travel, with the result that the effect of schedule quickening cannot be stated definitely.

VII. — FUTURE POLICY IN REGARD TO PASSENGER TRAIN ACCELERATIONS.

The replies received under this head lead us to the conclusion that, outside Great Britain, there is no settled policy among Railway Administrations in regard to the acceleration of their passenger services. In Great Britain, where it is the policy gradually to accelerate services wherever possible, replies from Administrations are qualified to the extent that technical, economic, or political developments may effect a policy of acceleration to such an extent that definite statements are not possible.

High-speed services.

The London and North Eastern report that their existing newly designed streamlined locomotives and coaches for high-speed services have given very satisfactory results, but that no forecast

can be made as to their future policy regarding such trains.

No other Administration mentions the possible introduction of high-speed services in the future.

Other services.

The London Midland and Scottish will continue a policy of accelerating its passenger services, particularly with a view to bringing a greater number of inter-city expresses up to a start to stop speed of 60 miles per hour.

On the London and North Eastern the question of the acceleration of passenger services is constantly under review.

The Southern will continue its policy of general and gradual acceleration as circumstances permit.

PART TWO.

THE SPEEDING UP OF PASSENGER TRAIN SERVICES BY MEANS OF RAILCARS AND THE FINANCIAL RESULTS OBTAINED BY THE METHOD.

The question of the evolution of railcars was reported upon very fully at the 13th Session of the International Railway Congress Association in Paris, 1937. It is therefore proposed in the present instance only to mention cases where modern railcars have been used to speed up passenger services.

Of the Administrations replying to the questionnaire on this subject, the following do not operate any railcars :

Southern (England),
Bombay, Baroda and Central India,
Burma Railways.

The following operate no modern railcars :

London and North Eastern,
Great Indian Peninsula,
South Indian,
Pennsylvania.

And the following operate modern railcars but do not use them to accelerate passenger services :

Great Western,
London Midland and Scottish.

The Egyptian State Railways report the use of diesel railcars for speeding up a branch-line service but render no additional particulars.

Similarly the Ceylon Government Railway mention that diesel units have been used to speed up passenger services on their Coast Line.

The Buenos Aires and Pacific state that railcars have been introduced for the purpose of speeding up branch-line services. The following particulars relate to that Administration.

Six 240-B.H.P. 60-seater cars fitted

with Ganz engines are in service. Three of these have mechanical transmission and three hydraulic drive. Their maximum speed is 63 m. p. h.

The average daily mileage per railcar in stock for these cars is 184 miles, with a maximum of 290 miles per day when on main line services and 382 miles per day on branch line services.

Two 120-B.H.P. 60-seater cars with Leyland engines are also operated and achieve an average daily mileage of 185 miles on branch or secondary lines.

On occasions when traffic is heavy the railcars are replaced by steam trains. Luggage is conveyed in a luggage compartment on the railcars. Parcels traffic is conveyed by steam trains or by a rail motor van (a railcar for parcels only).

Wherever possible railcars are used to supplant steam trains, but they also provide additional services not justifying steam traction. The only branch passenger services which may not be replaced by railcars are those consisting of a passenger coach attached to a freight train which runs as a « mixed » train on certain days of the week.

The Buenos Aires and Pacific report the allowance of 4 to 6 hours per car per day together with one shed day of 24 hours per week for the maintenance of railcars in daily service.

Periodical examinations are made every three months (18 600. miles). Three to five days per car are allowed. It is estimated that on the average major overhauls and examinations should be made after 75 000 miles.

At the present time the first general

overhauls of the railcars considered are only now being dealt with. Normally a general overhaul should take 15 working days.

The availability of the railcars in service, excluding time out of service for general overhaul, is 92 %.

The estimated life of these cars is given as :

Engine	8 years (600 000 miles).
Transmission . . .	12 years (900 000 miles).
Bogies and running gear	15 years (1 125 000 miles).
Body and interior .	20 years (1 500 000 miles).

The railcars are maintained at fixed depots, but up to the present time this has involved no empty running. Some expense has been incurred in providing covered stabling accommodation and fuelling plant.

The Buenos Aires and Pacific suggest the following factors and principles for the construction of railcars :

Weight per seat : Owing to need for luggage space it is difficult to fix a ratio. Cars built and building have approximately a ratio of 0.55 ton per passenger.

Power output per unit of weight : Not less than 6.5 to 1.

Number and arrangement of axles : Double bogie, engine preferably mounted on bogie.

Method of transmission : Mechanical and hydraulic are giving equivalent service on trial.

Maximum speed :

Branch lines	56 m. p. h.
Main lines.	75 m. p. h.

The Buenos Aires and Pacific expect

to standardize a 240-275 B.H.P. car with a power/weight ratio of 6.5 to 1 for branch line operation.

It has been found that on the Mendoza Division where railcars have been introduced passenger receipts have increased. Fares have simultaneously been reduced and so it is not possible to state what proportion of the increase can be accounted for by the railcar service.

The Administrations generally give no information to shew that the conditions or cost of maintenance of the permanent way have altered on lines on which railcars have been introduced, other traffic being the governing factor in these respects.

Present and future policy in regard to railcars.

Great Britain.

The Great Western report 17 44-seater 130-h.p. and one 44-seater 260-h.p. A. E. C. diesel cars in service and 20 additional cars on order. It is their policy to utilise these cars in substitution for steam train services with a view to effecting economy and for augmenting existing services experimentally in order to test traffic potentialities.

The present use of diesel cars on the Great Western is, to some extent, still experimental, but it is passing from this stage. In 1936, 641 500 passengers were conveyed in diesel cars; in 1938, this figure had increased by 341 876 to 983 376. The only additional expenses incurred have been in connection with providing covered stabling accommodation and fuelling plant.

At the moment 3 634 diesel car-miles are operated daily. The average daily mileage per car in stock is 206.

Examples of start to stop speeds at which the cars are booked are as follows :

From	To	Distance, miles.	Time, mins.	Speed, m.p.h.
Birmingham	Cheltenham Spa	54	60	54.1
Cheltenham Spa	Birmingham	54	59	55.0
Gloucester.	Newport	44 1/2	51	52.3
Newport	Gloucester.	44 1/2	49 1/2	53.9

The London Midland and Scottish operate 3 small 40-seater 95-H.P. Leyland railcars and are experimenting with a 750-H.P. 3-car articulated Leyland-engined diesel train.

The London and North Eastern are investigating the possibility of developing the use of railcars on branch lines.

The South Indian do not propose obtaining any additional railcars at the present time.

The Burma Railways are considering

railcars for trial purposes. If such trials were successful railcars would be used on short distance and suburban services.

* * *

The Buenos Aires and Pacific suggest that future development of high speed services will be by means of diesel engined cars in trains or units.

The Pennsylvania report no programme for the introduction of modern railcars on main or branch line services.

PART THREE.

CONCLUSIONS.

There is some difficulty in arriving at conclusions which are capable of universal application on account of the variations in the characteristics of the territories under review.

Despite this we offer the results of our survey as set out below.

I. There is a universal demand for quicker travel which can only be met by the acceleration of passenger train services. In certain circumstances the competition of other forms of transport, namely transport by air and by road, further stimulates action in this direction.

II. Not only must long-distance services be accelerated. There is an equal need for the quickening of short distance stopping services, particularly where road competition is operative.

III. The principal methods by which services can be speeded up are :

(a) The elimination of unnecessary intermediate stops.

(b) The reduction of the time trains spend over intermediate stops.

(c) The reduction of point to point running times by :

(1) Providing more powerful engines.

(2) Obtaining the maximum power from existing engines.

(3) Substituting electric for steam traction.

(4) Substituting diesel for steam traction.

(5) Reducing the trailing loads of trains by :

α — Limiting the number of vehicles to be conveyed.

β — Constructing special light weight vehicles.

(6) Raising the maximum permissible speed.

It is known that diesel railcars can be used to provide accelerated services but, in the present instance, insufficient data is available for any pronouncements to be made.

IV. The execution of train service accelerations will incur additional expenditure under various of the following heads :

(a) *Operating.* Particularly where it has been necessary to limit the number of vehicles conveyed on trains and to eliminate intermediate stops, additional train mileage will be required if the facilities previously offered are to be maintained.

(b) *Motive power.*

(1) Providing more powerful engines.

(2) Modifying existing engines.

(3) Electrification.

(4) Slightly increased maintenance

(c) *Rolling stock.*

(1) Providing special light-weight vehicles.

(2) Slightly increased maintenance costs.

(d) *Braking systems.*

Only where speeds are high will any expenditure be required in this direction.

(e) *Signalling.*

Where the increase in speed is considerable, extensive alterations to the positions of fixed signals and to systems of signalling will be necessary.

(f) *Permanent way and structures.*

Additional expenditure may be required to a limited extent on the permanent way, mainly in the following directions.

(1) Improvement of alignment;

(2) Somewhat earlier renewal.

In regard to structures it can seldom be said that expense is liable to be incurred by acceleration over and above the calls for normal development.

V. Where traffic is dense and the disparity in speeds of different classes of trains is wide the acceleration of passenger services will reduce line capacity and cause appreciable upset to other services. Where traffic is light no trouble will be experienced.

VI. The operation of trains at higher speeds has given momentum to the development of such refinements as make for more comfortable travel. In particular attention has been directed to improving the riding of passenger vehicles and reducing noise and vibrations.

In addition the passage of trains at higher speed directs attention to the necessity of greater exactitude in maintaining the line and level of the track.

VII. There is some evidence to show that a policy of accelerating passenger services will be appreciated by the travelling public, and that not only will traffic be retained by such means but also new traffic will be created.

* * *

ADDENDUM.

The following matter relates to the Madras and Southern Mahratta Railway of India, and was received too late for inclusion in the body of our report.

I. — Acceleration of train services.

This administration has accelerated its main line steam services and, by using diesel railcars, has also accelerated branch line services.

The speeding up has been largely the result of road competition.

Examples of the accelerations effected are as follows :

MADRAS AND SOUTHERN MAHRATTA RAILWAY.
Acceleration of Hubli — Poona service, 1935-1938,
(Metre gauge.)

From.		Hubli.	Poona.
To.		Poona.	Hubli.
Distance.		332 3/4 miles.	332 3/4 miles.
Journey time.	1935	17 h. 10 m.	16 h. 40 m.
	1938	13 h. 26 m.	12 h. 35 m.
Overall average speed.	1935	19.4 m. p. h.	20.0 m. p. h.
	1938	24.8 m. p. h.	26.4 m. p. h.
Number of intermediate stops.	1935	29	30
	1938	26	16
Reduction in overall journey time.		224 mins.	245 mins.

The extensive nature of the accelerations is illustrated by the following table :

MADRAS AND SOUTHERN MAHRATTA RAILWAY.
Comparative statement showing quickest overall time between certain important stations
in April 1929 and April 1937.

(5' 6" and metre gauge).

Between	Distance, miles.	April 1929		April 1937.		Reduction in overall time in 1937.	
1. Madras-Waltair.	485	H.	M.	H.	M.	H.	M.
		17	32	16	45	0	47
2. Madras-Cocanada Port	401	14	35	14	0	0	55
3. Madras-Nandyal	367	16	40	13	19	3	21
4. Madras-Bellary	307	12	51	10	20	2	31
5. Madras-Anantapur.	279	13	26	11	48	1	38
6. Madras-Tirupati East	91	4	8	2	36	1	32
7. Madras-Bangalore Cantonment .	222	6	45	6	13	0	32

Between.	Distance. miles.	April 1929.		April 1937.		Reduction in overall time in 1937.	
8. Madras-Hubli	436	H. 20	M. 45	H. 18	M. 5	H. 2	M. 40
9. Hubli-Bijapur	151	10	26	7	53	2	33
10. Hubli-Bellary	130	7	14	6	26	0	48
11. Hubli-Poona	334	18	10	13	30	4	40
12. Hubli-Belgaum	88	4	47	3	28	1	19
13. Poona-Kolhapur.	190	10	30	8	17	2	13
14. Poona-Belgaum	246	13	4	8	49	4	15
15. Poona-Mormugao	363	22	45	16	30	6	15
16. Bezwada-Guntakal.	279	19	5	13	15	5	50

The methods used have been :

1. The elimination of intermediate stops.

2. The reduction of time spent at intermediate stops.

3. The reduction of the trailing loads of trains. Between Hubli and Poona the train load prior to acceleration was 25 units, after acceleration it was 22 1/2 units.

4. By obtaining a greater power output from existing locomotives on steam services.

5. By substituting diesel for steam traction on some branch services.

Locomotives of greater tractive effort have not been built, nor has streamlining been adopted. The question of constructing a lighter type of passenger coach is under investigation. Maximum permissible speeds have not been raised.

In regard to the cost of the acceleration of services the Administration reports that no additional works, improved layout of lines, improved design of

permanent way, bridges or signalling have been necessary, nor has there been any effect on the upkeep of the permanent way.

No details are available as to the effect upon locomotive or rolling stock maintenance costs.

It is reported that the improvements in train services have been greatly appreciated by the travelling public.

No future programme of train service acceleration is in view.

II. — Railcars.

The Madras and Southern Mahratta Railway operate six 5' 6" gauge diesel-electric 140-H.P. railcars purchased in 1935. The cars are based on one depot and work services on main and branch lines aggregating 836 miles daily. One car out of six is spare.

The railcars have been used both to replace steam trains and to provide additional services, but only on branch lines have they been used to reduce overall journey times.

The following is an example of the acceleration achieved :

MADRAS AND SOUTHERN MAHRATTA RAILWAY.
Acceleration of branch line service by means of diesel railcars.

From.		Cocanada.	Somagundam.
To.		Somagundam.	Cocanada.
Distance.		29 miles.	29 miles.
Overall journey time.	Steam train.	1 h. 39 m.	1 h. 42 m.
	Railcar.	1 h. 27 m.	1 h. 30 m.
Overall average speed.	Steam train.	17.6 m. p. h.	17.1 m. p. h.
	Railcar.	20.0 m. p. h.	19.3 m. p. h.
Number of intermediate stops.	Steam train.	7	7
	Railcar.	14	14
Reduction in overall journey time.		12 minutes.	12 minutes.

The chassis of the diesel-electric railcars operating such accelerated services were purchased from Messrs. Armstrong Whitworth and fitted with 110-seater bodies built in the shops of the Administration. The weight of the railcars is 34 tons, giving a power/weight ratio of 4.1 and figure of 0.313 tons tare weight per third-class passenger seat.

The railcars run on two four-wheel bogies. Transmission is A. B. E. simplified electrical through worm and wheel to axle. Maximum speed with full load on level, 40 to 45 m. p. h.; and on a 1 in 100 gradient, 27 to 30 m. p. h.

Provision is made for the conveyance of a limited quantity of luggage and parcels traffic. Two railcars can be coupled together and run as one, but individual railcars cannot haul trailers.

Six hours are spent on each car once a week for general maintenance, and two to three weeks per engine for periodical overhaul. The mileage run between each engine overhaul is 20 000 to

25 000, and the corresponding normal periodicity 4 to 5 months.

It has been the experience of this Administration that the replacement of steam trains by railcars is accompanied by a substantial reduction in working costs.

The following particulars have been submitted for the Cocanada-Kotipalli branch.

**MADRAS AND SOUTHERN MAHRATTA
RAILWAY (COCANADA — KOTIPALLI
BRANCH).**

**Commercial and financial results of
introducing railcars, May, 1935.**

Year.	Passenger density.	Working expenses.	Net deficit on branch line.
1934-35	100	100	100
1935-36	122	73	52
1936-37	136	64	30
1937-38	143	59	21

The Administration reports that this branch was opened in 1929 and has never covered its working expenses. The goods traffic turned out to be negligible and there is intense and uncontrolled bus competition. In addition, the stations were badly sited and in some cases the local Municipalities would not connect the stations with the town by road.

The passenger density was 200 000 per mile per annum in 1930 and this had fallen to 93 000 just before railcars were brought into use. For the first six months the cars were operated without reductions in fares, no steam trains being run, to test the effect of a fast and fairly frequent service with several additional halts between stations.

Fares were then reduced, and, compared with 1934-35, the passenger density and earnings have increased as shown in the table given above. In comparison, on nearly all other sections of the lines operated by this Administration, passenger density has decreased in these years.

The Madras and Southern Mahratta Railway report that there can be no doubt that the diesel railcars have proved a success in spite of initial difficulties, but that it is necessary to emphasise

the need for expert maintenance. The railcars must operate round a centre at which this necessary attention can be given; they cannot be sent at present to work at isolated places. Further, as this special maintenance is costly, it is not economical to provide it for a small number of railcars.

There are also collateral concealed savings where railcars can entirely take the place of steam trains, track upkeep is less costly and it is possible to do with less, or even without any, ballast. When a halt is introduced only a very short inexpensive platform is required, instead of a platform extending nearly the whole length of a train. Further, the axle loads being small, much higher speeds can be sanctioned for railcars than for steam engines on light track.

It is becoming apparent that there is a considerable field for railcars, and there are many places where they would be put on today if suitable railcars were available. The main difficulty in India is to find a railcar of low initial and running costs which can be operated for the conveyance of traffic at the extremely low fares current and the still lower fares which it is being found it is necessary to quote in competition with road transport.

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NOTE. — Replies to the questionnaire were also received from the East Indian Railway, Calcutta, and from the Central Argentine Railway, Buenos Aires, but these replies were received too late to be included in the above report.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

INQUIRY INTO QUESTIONS OF GENERAL INTEREST.

(Decision taken by the Permanent Commission at its Meeting held on July 9th, 1938.)

QUESTION II.

How should the problems of simplifying the working be considered, in the future, in the interest both of the public and of the railways?

REPORT

(Secondary Railways),

by Dr. Gr. Uff. PIETRO LO BALBO,

President, « Società Anonima Tramvia Dogliani Monchiero » (Italy).

The economic effects of the world crisis have forced railway experts and managements in all countries to study the problem of simplifying the operating in order to bring it into line with present-day economics and the new requirements of the public.

At the Paris, 1937, Session, the International Railway Congress Association discussed « the economical operation of the main line railways' secondary lines » (3rd Section — Question VII).

The Permanent Commission of the Association considered that it would be a good thing, in view of the frequent deficits in railway balance sheets, to bring to the notice of the railways any developments in this connection, and in particular the results obtained and the new methods introduced or proposed since the last Session.

The present report, dealing with secondary lines and concerned with their economical operation, is intended to complete the information collected in 1937.

A questionnaire was sent to the railways belonging to the International Railway Congress Association, and we wish to thank them for all the information they so kindly sent.

Secondary lines with simplified operating may themselves be grouped into two main categories, as follows :

(1) lines with passenger and goods trains;

(2) lines on which the passenger services have been discontinued, and only goods trains are still run.

The simplification principles applied to each of these categories are the same, and consist in general of using the most economical and up-to-date technical methods to reduce costs whilst at the same time making it easier for the public to travel, and encouraging the recovery of traffic.

Amongst the general measures taken to reduce costs we may recall: standardisation of rolling stock; less stringent working regulations (abolition of keepers at level crossings, either completely

or partly; doing away with signals governing the entry into stations); the simplification of the station working and of some of the regulations applying to the rolling stock; limiting the hours during which stations are open to the public; contracting out certain services in connection with the operating (ordinary and special repairs to rolling stock, station shunting services, ordinary maintenance of the permanent way). In addition, the dispatching system (a single official in charge of traffic control) has latterly been better adapted to lines with little traffic.

All efforts made to simplify the services have given excellent results from the point of view of reducing the operating costs.

To encourage the recovery of traffic, the greatest attention has been paid to the rolling stock, with a tendency to lighten still further both the vehicles and locomotives by the use of high-tensile steels, light alloys, and the adoption of welded tubular structures.

In addition the use of light trains formed of railcar units giving a fast and frequent service, has been extended.

It must be pointed out that on certain secondary lines, the simplification of the operating has consisted mainly in the replacement of the steam locomotive by the railcar (internal-combustion-engined) for passenger services.

On the 3 376 km. (2 095 miles) of lines owned by the *Belgian National Light Rys. Co.*, 250 railcars have been put into service, and the steam services in this way restricted to goods and special services only. The excess staff is temporary unattached, or is pensioned off.

The motive power and rolling stock used by this Belgian Company has the following characteristics :

Internal-combustion-engined railcar S. N. C. V. type; frame carrying a 6 cylinder Brossel diesel engine; power 125 H.P.; direct turbulent injection; disc clutch; gear box and differentiel assur-

ing the independence of the pairs of wheels; two cardan shafts and two worm axle drives. Body with two driving compartments. Maximum speed 45 to 65 km. (28 to 40 1/2 miles) an hour according to the line on which the vehicles are worked.

On the *Halmstad-Nässjö Ry.* (Sweden) there are two types of railcars built by the Carlsson Works, at Umeå :

(1) with four wheels; weight in working order 6 tons, 24 seats, standing room for 26;

(2) with eight wheels; weight 10 tons; 46 seats, standing room for 24.

Both are equipped with 120 H.P. Scania petrol engines; maximum speed 80 km. (50 miles) an hour.

In Italy, the Fiat railcar, the « *Littorina* » ⁽¹⁾ has successfully solved the fundamental problem of economical operating, as this vehicle has been designed to be a typical railway vehicle with all the qualities of a road motor car, i. e. :

(1) rapid starting and braking; (2) high maximum speed; (3) sufficient reserve power in the engine to meet possible excessive demands.

The « *Littorines* » are generally single-class vehicles built of light alloys or special steel; the average weight is about 200 kgr. (440 lb.) per passenger. The power is 10 H.P. per ton under full load, which favours a good user with low operating costs. The very low centre of gravity makes it possible to run at high speeds even through sharp curves. Thanks to the specially designed mechanical transmission, the efficiency figures reached are 95 % on the direct drive and 89 % through the gears.

One of the chief advantages of this railcar is its great adaptability to various kinds of services, always with maximum efficiency and minimum cost.

(1) From Littoria, the new city built on the Pontine Marshes.

This particular characteristic means that the « Littorine » meets the most varied railway requirements satisfactorily, the original design being given such variations as required to adapt it to each new employment.

This has led to a whole range of different types of « Littorines » being designed recently : vehicles with a single engine; vehicles with two engines; vehicles about 13, 15, 18 and 23 m. (42' 8", 49' 2", 59' and 75' 5") long; 36 to 80 seats; standard and narrow-gauge vehicles; vehicles with diesel engines and vehicles with petrol engines.

In *Great Britain*, the railways now have a preponderant influence on inter-urban omnibus traffic. Motor vehicles belonging to the railways are used for such passenger services. Thanks to the introduction of combined tickets for rail and omnibus travel, the combined services work very smoothly.

In *Sweden, Switzerland, and Italy*, at certain departure stations, ordinary and season tickets available by rail and road are issued. The price is obtained by adding the fares on the respective lines.

In *Switzerland and Czechoslovakia*, auxiliary services have been organised

Leading dimensions and characteristics of some types of « Littorine » railcars.

TYPE.	23-m.	23-m.	23-m.	18-m.	18-m.	15-m.
Length	{ m. 23 330 ft. in. 76' 6 1/2"	{ m. 23 516 ft. in. 77' 2"	{ m. 22 816 ft. in. 74' 10"	{ m. 18 416 ft. in. 60' 5"	{ m. 17 895 ft. in. 58' 8 1/2"	{ m. 15 095 ft. in. 49' 6"
Width	{ m. 2 600 ft. in. 8' 6 3/8"	{ m. 2 700 ft. in. 8' 10 5/16"	{ m. 2 900 ft. in. 9' 6 1/4"	{ m. 2 400 ft. in. 7' 10 1/2"	{ m. 2 400 ft. in. 7' 10 1/2"	{ m. 2 400 ft. in. 7' 10 1/2"
Seats	80	40 and buffet	80	56	64	48
Weight empty	{ kgr. 21 000 lb. 46 300	{ kgr. 24 500 lb. 54 000	{ kgr. 25 000 lb. 55 100	{ kgr. 18 000 lb. 39 700	{ kgr. 15 000 lb. 33 100	{ kgr. 14 000 lb. 30 900
Weight fully loaded	{ kgr. 28 000 lb. 61 700	{ kgr. 32 000 lb. 70 500	{ kgr. 35 000 lb. 77 200	{ kgr. 25 000 lb. 55 100	{ kgr. 21 000 lb. 46 300	{ kgr. 18 000 lb. 39 700
Number of motor bogies.	2	2	2	2	1	1
Total horse-power	230	290	290	160	120	120
Type of engine	diesel	diesel	diesel	diesel	petrol	petrol
Speed on the level.	{ km./h. 120 m.p.h. 75	{ km./h. 135 m.p.h. 84	{ km./h. 115 m.p.h. 71 1/2	{ km./h. 110 m.p.h. 68 1/2	{ km./h. 105 m.p.h. 65	{ km./h. 115 m.p.h. 71 1/2
Fuel consumption (according to the gradients of the line)						
about	{ gr./km. 500 lb./mile 1.77	{ gr./km. 650 lb./mile 2.31	{ gr./km. 700 lb./mile 2.38	{ gr./km. 350 lb./mile 1.19	{ gr./km. 330 lb./mile 1.17	{ gr./km. 300 lb./mile 1.06

In certain cases the railway services are supplemented by omnibus services on roads adjacent to the railway (Karlskrona-Växjö), and the rates are completely independent.

There are also secondary railway lines where bus tickets can be used either on the buses or on the railway; on the other hand the railway tickets are not always available on the buses owing to lack of room.

on certain railway lines (door to door services) to convey passengers between the stations and towns lying at some distance therefrom.

In the case of goods traffic, at the present time many Railway Companies are interested in lorry services to complete their rail services. Some Companies even collect and deliver rail traffic free of charge, i. e. without increasing the rates; the information received is in

favour of this system which is not a simplification, but a means of keeping goods traffic for the railway.

In certain cases, when the operating results show a deficit, the railway services have been completely discontinued and the passenger services are worked by trolleybus or motorbus instead of by rail. The equipment of such lines has been disposed of.

Compared with the secondary railway services, these substitutions have nearly always led to an improvement, when the insufficiency of the rail services is borne in mind on the one hand, as regards speed and connections with towns in mountainous country, and on the other hand the greater facility with which new services can be introduced with motor vehicles to meet the new needs of the public.

Sometimes the substitution of omnibus services for secondary railways is found to be advantageous not only for the public, but also for the Railway Administration from which it removes very heavy burdens.

In principle the omnibus services replacing rail services are operated by the Railway Companies themselves. In some cases, certain services conceded to them by reason of the laws in force are contracted out (with the authorisation of the public authorities) by agreement, on payment of a royalty to the Railway Company.

Generally speaking, when all the passenger trains have been suppressed, the railway rates are applied to the bus services taking their place. The reductions granted by the railway are not always extended in their entirety to the bus services. Only in the case of additional services — asked for or required by the authorities granting the concession — are the fares independent, and in particular the reduced fares in force on the railway do not apply to the bus service.

In *Italy* during recent years the use of trolleybuses in place of certain secondary railway lines has been greatly extended. This method of transport is increasing thanks to its technical improvements, and also on account of the necessity for faster and cheaper transport than is possible by rail. The Government subsidises the introduction and working of trolleybus lines (by the law of the 23rd December 1937, the concession period has been increased to 30 years, and the State subsidy has been increased to a maximum of 5 000 lire per kilometre for the whole period).

One example of the complete substitution of omnibus services for the railway service of a secondary line is that recently decided upon in *Sicily*. Here the railway system consists of a dozen lines totalling some 563 km. (350 miles), 49 km. (30 miles) being rack railway. The operation of these lines showed a deficit of some 17 million lire per annum, on a total expenditure of some 23 millions, i. e. these lines with receipts of 6 millions cost nearly four times as much to work.

The replacement of these lines by omnibus services has been put into the hands of the National Transport Institute (an organisation created by the railways themselves) which prepares to put into service the most up-to-date motor vehicles for the transport of both passengers and goods, which means that the communications already in existence will be speeded up and intensified, and new services introduced, thereby contributing largely to the development of the island which, thanks to the efforts of the Fascist regime, is playing an ever greater part in the economic life of the nation.

As for the results already obtained in recent years, we may mention that on the 3 376 km. (2 095 miles) of the *Belgian National Light Rys.*, with steam operation in the case of goods services

and railcars for passenger services, the increase in the receipts in 1936 was 10.7 % compared with 1935, 5.8 % in 1937 compared with 1936, and 2.09 % in 1938 compared with 1937. The number of passengers increased from 17 724 476 in 1936 to 20 008 832 in 1937, and 19 millions 844 666 in 1938. The increase in the number of train-kilometres on these lines was 19.78 % in 1936 compared with 1935, 4.2 % in 1937 compared with 1936, and 1.32 % in 1938 compared with 1937.

At the end of 1938, on the 164 lines in operation, only 62 still showed a deficit, whereas formerly 84 were always run at a loss.

In *France*, thanks to the suppression of a certain number of trains on several secondary railways and their replacement by railcars or an omnibus service, there has already been an appreciable decrease in the traction costs, as follows :

Cost of traction per train-km. on the average, 15 francs;

Cost of traction per railcar-km. on the average, 10 francs;

Cost of traction per omnibus on the average, 4 francs.

This means that if four journeys there and back by rail are replaced by six there and back by omnibus (the proportion according to which the substituted services have generally been organised) there is a reduction in cost, i. e. a saving, of about 26 000 francs per kilometre per annum. This does not take into account the other savings of approximately 8 000 francs per kilometre per annum due to the elimination of certain level crossings and keepers, and approximately 4 000 francs for other railway operating costs.

Altogether the substitution of the omnibus for the passenger train means an annual saving of 38 000 francs per kilometre. When the omnibus takes the place of a railcar service, the saving is

about 28 000 francs per kilometre per annum.

In *Italy* the use of « Littorine » railcars on various secondary lines has led to a marked improvement in the services, which has had a definite effect on the receipts, together with a remarkable increase in the traffic.

This result, together with the low annual costs of the « Littorines » (which is 1/4 to 1/5 that of the corresponding steam trains) has contributed to a large extent to improving in a very short time the economic results of the reorganised and simplified operating due to the introduction of these railcars.

SUMMARY.

In all countries, the Secondary Railway Companies during recent years have made a great effort in two complementary directions : to react to the transport crisis due to the stagnation of economic and international activities, and to meet the situation due to the development of road transport.

Everywhere the need has been felt for general simplification of transport legislation to make it conform more closely to the nature of the railway lines and to obtain collaboration between the main-line railways and the secondary railways, by means of which the burdens on the secondary lines can be lightened to a reasonable degree.

As regards the operating, the simplification of the services has taken place with a certain degree of uniformity. General economies have been made in all the services, and reduced expenditure has been sought in particular in the field of technical equipment in order to adapt it to real traffic requirements : — simplification of the signals and even elimination of same where possible; reduction of the number of stations; simplification of the working of points and of the traffic regulations, of the rates assessment and accountancy; elimination

of keepers at certain level crossings; acceleration of the turn-round of rolling stock, and finally the use of lighter and shorter trains, and the substitution of railcars for steam trains.

The economies obtained by using railcars are primarily due to the reduction in expenditure of staff and fuel, as well as to the advantage of higher average train speeds.

In order to keep the place they held in the transport industry, certain railways have not been content merely to improve their rail traffic by using rail-

cars, but they have further strengthened their position in the face of competition by making agreements with carriers, or making use of omnibus services themselves in order to increase their efficiency in this way.

Finally in the case of those secondary railway lines with a large deficit, the tendency is to transfer the transport entirely to the road, which makes it possible to recover the passenger traffic, shorten the journey, give a better service to the districts concerned, and finally realise considerable savings.

April 1939.

Coupled and twin railcars,

by Mr. TOURNEUR,

Engineer, Research Department, Western Area, French National Railways Company.

(*Revue Générale des Chemins de fer.*)

When in 1933, the French Railways began to develop railcar services, the engines available were of low power, and the principle which then obtained was that of the light vehicle, always operating as a separate unit, and, consequently, provided with very elementary coupling gear, designed for use exclusively in the event of breakdown.

Without going into the evolution of railcar operation, which would be beyond the scope of this article, let us remember only that the necessity of being able to meet fluctuations in the volume of traffic, not only by increasing the number of services, but also by varying the capacity of motor trains, quickly became apparent.

At present this result is obtained by using coupled railcars, twin railcars and trailers.

Railcars capable of working coupled together are fitted with remote controls, which enable the driver of the leading car to operate the mechanisms of the two cars simultaneously. The presence of a second employee in the trailing railcar is not necessary as this means, after all, the extension to railcars, of multiple-unit driving, which has been employed for a long while in electric traction.

On other hand, railcars working as twins both have a driver, and the one in the leading car advises his colleague, with the aid of suitable signalling apparatus, what operations to perform in the trailing vehicle. In some cases, however, the brakes of both vehicles are normally under the control of the driver in the leading car.

The use of trailers is more recent, only having become possible when engines sufficiently powerful to develop at least 500 H.P. in one vehicle became available. From our point of view, these powerful railcars are not equipped with any special apparatus. They are usually provided with lightened standard coupling gear, which enables them to haul a fast goods wagon or a through coach coming off a long-distance train and proceeding to a locality on a branch line.

We propose, in the following, to give some idea of the mechanism peculiar to coupled and twin railcars, beginning with the coupling gear, which is common to both.

Coupling gear.

To facilitate working at termini, the railcars which we are considering nearly all have Willison automatic coupling (fig. 1), an American coupling of the « free » type, that is to say, one of the coupling heads is able to slide vertically with respect to the other. The addition of a Robinson coupler makes automatic coupling of air pipes and electric cables possible. This apparatus is fitted to the Baudet-Donon and Roussel railcars in the South-Eastern Area ⁽¹⁾.

Some Michelin railcars which can be

(1) Although it may have no bearing on railcars, remember that the electric motor coaches on the Paris-Le Mans line are equipped with rigid automatic coupling gear, Boirault « compact » type (fig. 2); further, the German Scharfenberg coupling gear is being tried on railcars in the Northern Area.

run as twins are fitted with special coupling gear designed by the Michelin Works (fig. 3); this very light, semi-automatic coupling gear is formed by two horns bolted to the chassis through rubber washers, which leave them some freedom of movement, and connected by a drawbar carrying interlocking mechanism.

Special parts of coupled railcars.

Coupling of railcars with mechanical transmission necessitates remote con-

motion, when letting in the clutches is important. With ordinary mechanical clutches, the characteristics of which are not very constant, the required result can only be achieved by acting on the clutch and the fuel injection simultaneously and skilfully. On a railcar operating as a separate unit, where the driver has only one or two transmissions to control, and where, above all, he is aware immediately of the effects of his operations, a little practice suffices to enable him to obtain correct results.



Fig. 1.

trol of clutches, reversing gears, gear-boxes and injection of fuel into the cylinders of the engines (or butterfly valves of carburettors in the case of petrol engines).

At the moment of starting two coupled railcars, it is important, to prevent troublesome reactions, that the efforts at the wheel rims of both vehicles remain constantly proportionate one to the other, especially during the period immediately following the putting of the cars into

Besides, even on railcars with two engines, proper synchronisation of both clutches can be accomplished comparatively easily with careful maintenance. Quite different conditions arise when any two railcars have to be worked simultaneously, for the clutches and the fuel injection have to be controlled in the same way on both vehicles. This is one of the most critical points in the coupling of railcars with mechanical transmission. On the perfect matching

of injection controls depends good distribution of the power developed during the journey.

Clutches and injectors are usually pneumatically controlled with the aid of compressed air pipes connecting the two cars. Synchronisation of clutches is achieved by means of ports of suitable

ed by means of wires, and sometimes they are simply electric (Cotal).

It should again be noted, in this connection, that correct passage through the gears means that after declutching and reducing the fuel supply the speeds of the engines must decrease synchronously, so that these speeds be equal at

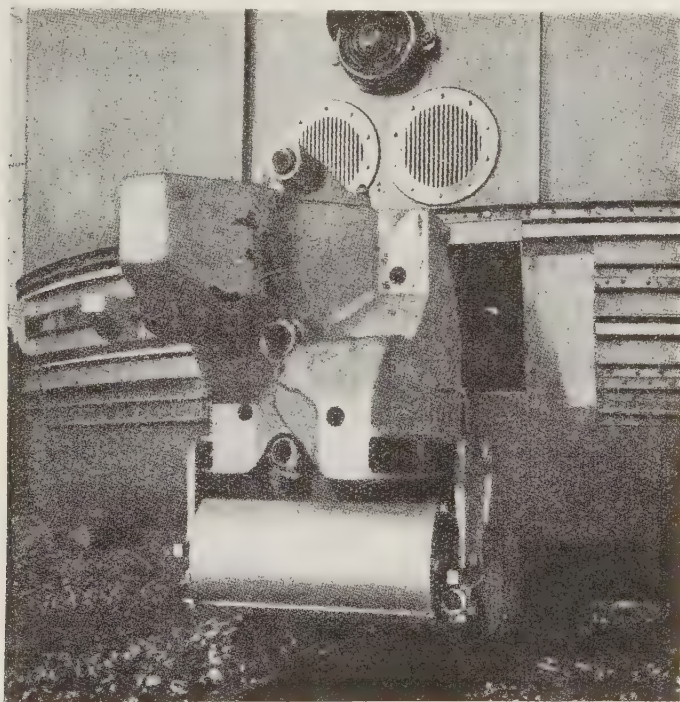


Fig. 2.

size and expansion chambers. The fuel pump rodding is usually moved by means of a cylinder, in which air reacts on a suitably controlled spring; the position of the rodding depends on the varying pressure produced by the driver in the control pipe.

Remote controls for reversing gears and gearboxes do not present any difficulty; they are usually electro-pneumatic, with electrovalves remotely controll-

the moment of clutch engagement; here again, the speed governors must be similarly regulated.

In practice, improved apparatus now enables coupled railcars with mechanical transmission to work well, but at the expense of appreciably more difficult maintenance.

It is essential, of course, that the driver should control the speed of the engines and the working of the reversing

gears and gearboxes ⁽¹⁾; this control is realised with the aid of pilot lamps and remotely controlled speedometers. The connections made necessary by the coupling up of railcars are therefore fairly numerous : on the Renault ABJ type railcars, with one 300-h.p. engine, for example, they already comprise sixteen electric wires and one air pipe ⁽²⁾, and the Dietrich railcars, with two

electric control, not having the least consequence. It is important, however, that the regulation of the speed of the generator sets be correct. These controls are generally fairly simple (eight wires between Berliet railcars with two 150-h.p. sets).

Special parts of twin railcars.

The first railcars designed for twin



Fig. 3.

150-h.p. engines, require fifteen wires and four air pipes for coupling them up.

With railcars with electric drive, coupling does not present any particular difficulty, the control devices (resistances) remaining invariable in time, and an imperfect synchronisation, which is not moreover to be feared with all-elec-

operation were the Michelins « fifty-six seater » type, put into service in 1934. These reversible vehicles, with a single raised driver's cabin, have in each cabin a galvanometer connected by wires running to potentiometers, fitted in each car and working in conjunction with the fuel control levers, so that the galvanometer needle is at zero when the levers occupy the same position. The driver of the trailing car, who can also see his colleague in the other car because of the positions of the cabins, has

(1) An unsuccessful operation at the start may cause racing of a motor whose gearbox would remain at a lower speed.

(2) There is no gearbox control.

only to watch his galvanometer and work the accelerator so that the galvanometer needle remains at zero; he thus equalises the load on the engines of the two cars. The galvanometer and speedometer readings enable him to judge the right moment at which to change gear.

pes, of the Lyons depot, then to the Bugatti 400-H.P. railcars; more recently, it has even been found possible to authorise twin working of Renault diesel-mechanical railcars and Berliet diesel-electric railcars over some lines, with the reservation that precaution should

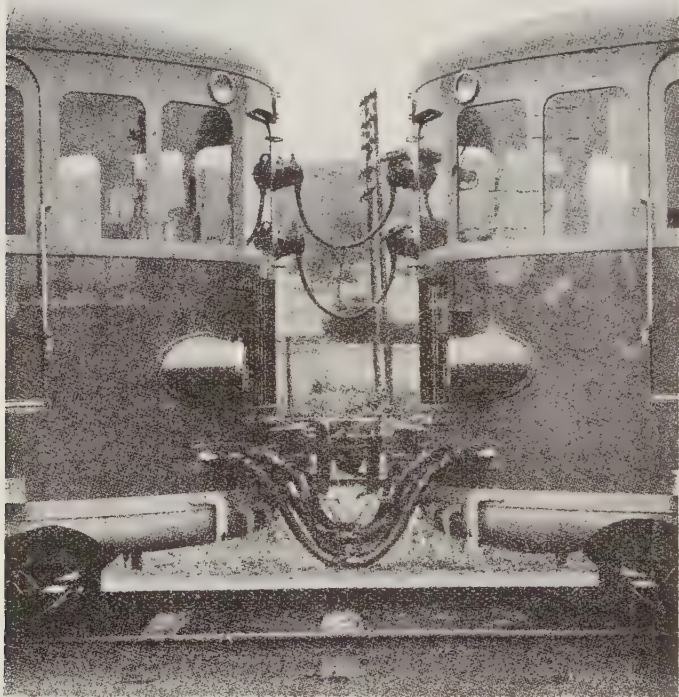


Fig. 4.

Because of the good results obtained with these Michelines, and their performances comparing favourably with the possibilities offered by the coupled railcars already in service, twin operation has been extended progressively to several other series of railcars, especially the Renault VH, ABJ and ABV ty-

pe to prevent overloading the railcars with electrical transmission.

On the majority of railcars that can be worked as twins, orders are given by the driver in the leading vehicle to the driver in the trailing railcar (starting, changing gear, braking, etc.) by lighting, according to a convenient code, a

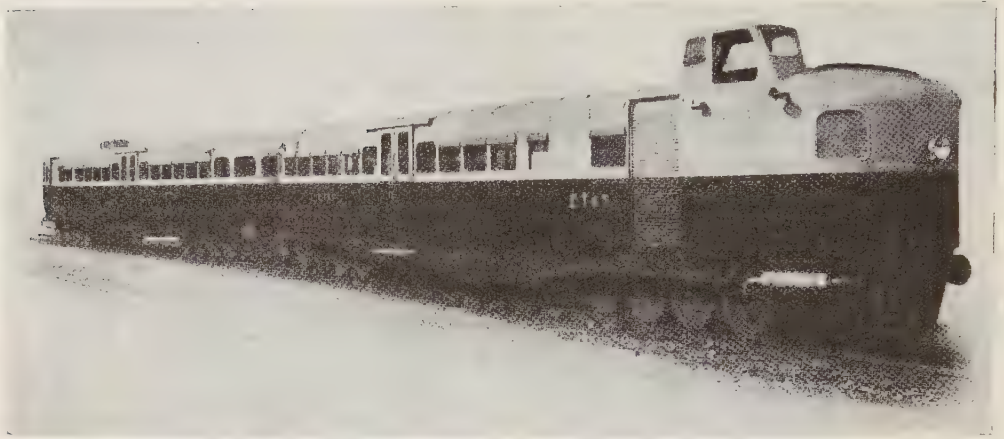


Fig. 5. — 56-seater Micheline twin railcars.

lamp placed at the rear of the leading railcar and easily seen from the cabin of the trailing vehicle. On some recent cars (Bugatti), wires connecting the two vehicles enable tell-tale lamps in the cabin of the trailing railcar to be lit to correspond with the operations performed in the leading railcar.

Usually the leading car starts first, and the driver of the trailing car lets in the clutch when the couplings are taut.

Twin operation of railcars not originally designed for this purpose has given rise to some difficulty in cooling the engine of the trailing railcar, as the radiators of old cars have not usually forced ventilation.

It should be noted that the principle of twin working has inspired in the Northern Area a solution to the problem of shunting at termini, in the case of railcars coupled to trailers, to bring the railcar to the head of the set. At the end opposite to the railcar, the trailer has an observation compartment occupied by the driver, from which he can work the

brakes of the train and the self-registering signal apparatus and give by optical signals, orders relative to the operation of the engine and transmission to a second employee in the railcar.

It would still be premature to express an opinion on the future of each of the three methods of using railcars we have just examined; it is, moreover, much more a problem of operation than one of construction.

We think, however, that twin operation only constitutes a transitory and imperfect solution from a technical point of view, but it is justified at present, because it allows railcars which have not been specially designed for the purpose to work together, and because the coupling of railcars with mechanical drives still requires very careful maintenance. We can, however, anticipate that the improvements that are being made to these drives, especially the use of automatic clutches, will make possible in the future completely satisfactory coupling of railcars with mechanical transmission.

A new high-speed diesel-electric railcar set for the German Reichsbahn.

(Glaser's Annalen.)



The complete railcar set.

Early in February, 1938, a new high-speed diesel-electric railcar set for the German Reichsbahn, containing the latest developments in railcar construction, was delivered by the M. A. N. Works, Nuremberg. As the existing two and three-unit sets were proving insufficient for various important lines, the new set was made up of four units. By this means it was possible to increase the seating capacity and at the same time provide a greater degree of comfort. The required speed of 160 km. (100 miles) an hour and the fairly considerable weight of over 200 t. (196.8 Engl. tons) necessitated an engine power of 1300 h.p.

In the previous railcar sets it had been the practice to provide the motive power from several engines mounted on the bogies but, in the light of experience, the entire motive unit for this train has, for the first time, been grouped in a special motor coach. The motor unit

consists of an eight-cylinder, M. A. N. four-stroke, diesel engine, built by the Augsburg Works, together with a generator which gives a sustained power at 700 r.p.m. of 1360 h.p., this being the most powerful railcar motor unit yet provided by the Reichsbahn. An auxiliary diesel-generator set of 150 h.p. provides supplementary current for all the auxiliaries, such as the air compressors for the brakes, lighting, ventilation motors, accumulator charging, etc.

In the front of the motor-coach is a driving cabin, separated from the engine room by a heat- and sound-insulating partition. At the rear of this vehicle are a mail compartment and a luggage compartment provided with the usual fittings. On account of the high weight of the engine — 34 t. (33.5 Engl. tons) — the underframe of the coach is of unusually robust construction, and is completely welded, as is the whole train.



Interior view of the dining compartment.

The two vehicles next to the motor coach are passenger coaches. They each contain nine second-class compartments which are separated from a side corridor by a partition with sliding doors. The tail coach also contains three similar second-class compartments, followed by a dining compartment with 29 seats, a pantry and a kitchen. This arrangement is a particular improvement of the new set over those previously used, which were provided either with very limited dining facilities, or none at all. The tail coach is completed by a driving cabin similar to that at the head of the train, with the necessary controls for driving the train. The railcars can thus be driven in either direction.

Contrary to former practice, each of the cars is supported on two four-wheeled bogies. The two pairs of wheels of each inside bogie of the motor coach and of the tail coach are driven from electric motors of about 200 kw. each, worked by current generated from the main motor unit.



Engine room.

The four coaches are close-coupled by Scharfenberg automatic couplings, and are provided with flexible fairing between the coaches, so that the whole set gives an appearance of unbroken continuity. The cars are provided with air brakes, magnetic rail brakes, and hand brakes. In addition, they are equipped, as in the case of all high-speed railcars, with inductive automatic train control equipment. Beneath the outer doors of the passenger coaches electrically-operated folding steps are provided, illuminated from the side, and worked by remote control from the driving cabin.

The inside arrangement of the passenger compartments offers a very luxurious appearance, and gives a maximum of space and comfort. The available

floor space for each seat has been increased to one and a half times that provided in the railcars at present in service. The inside walls are of grained walnut, with a ceiling of maple. Particular attention has been given to the provision of efficient ventilation in the passenger vehicles, these three coaches being equipped with thermostatic control, which may, in winter, be adjusted to provide automatic heating and air circulation. In summer, when heating is not required, the air current is circulated in reverse direction, from the top downwards, through the compartments, which it cools.

The outside of the set is painted in violet and cream shades and the total length of the set is about 87 m. (285 ft.).

[62. (01 (42) & 623. 4 (42)]

Silencing London's Tubes ^(*),

by JOHN S. TREVOR,

Leighton Buzzard, Bedfordshire, England

(From *Transit Journal*.)

Long sections of continuously welded rail and wall screens of perforated asbestos wood have proved highly successful in reducing noise.

Steel rolling stock operating through the cast iron tubes forming an important part of London's extensive network of underground railways created a noise problem which was receiving attention even before the World War. When the purchase of new rolling stock was proposed after the end of hostilities, the opportunity was taken to investigate the whole problem thoroughly.

Attempts to introduce specially-insulated, air-conditioned cars with closed windows were not successful. The pu-

blic quickly showed its dislike of being boxed in and frequent attempts were made to open windows and so destroy the usefulness of the air-conditioning system. It was soon realized by the London Passenger Transport Board that the most practical method of improving noise conditions lay in preventing noise at its source.

Attention was given to improvement of the track. A number of interesting experiments were carried out with various forms of track construction, including

(*) *Editor's note.* — This article describing the latest sound reduction methods in use in London was specially prepared for « *Transit Journal* » by the author with the cooperation of London Passenger Transport Board.



Panels of perforated asbestos wood from the track up to the level of the car floor are used in London tubes to absorb noise of passing trains.



Screwing the panels to steel brackets which are welded to the segments of the tube.

sleepers supported in the middle with the ends overhanging, sleepers completely embedded in concrete and sleepers held only at the end, the middle being unsupported. None of these variations gave sufficient reduction to encourage hope that the problem could be solved by changes of construction. In fact no very noticeable difference was apparent until ballast of considerable depth, up to above the level of the top of the sleepers, was tried.

In 1933 rails 90 ft. in length were used on a new extension of the Piccadilly line from Finsbury Park to Cockfosters, and a considerable reduction in rail joint noise was experienced. The permanent way department of the Board came to the conclusion that if rail joints could be eliminated a large percentage of the noise would be prevented at the source. They therefore turned their attention to the possibilities of welding 90-ft. rails together to make one continuous rail. On an experimental section of the Northern Line between Goodge Street and Tottenham Court Road, 90-ft. rails were installed and treated in this way. The surface of the rails was then made smooth by running over the section a car fitted with special grinding blocks. This resulted in a reduction of noise of 40 per cent.

At the same time experiments were made in the absorption of sound. Mattresses of asbestos fiber in woven asbestos cloth were placed in a vertical position alongside the track, reaching from the floor of the tunnel to the floor level of the train, and as close to the train as possible. This treatment reduced noise by another 20 per cent.

This method, however, was found to suffer from one rather serious drawback. The mattresses formed a pocket for the collection of dust which could be readily ignited by a lighted cigarette end, or even the hot ash from a cigarette or pipe. Although the risk of serious fire from such a case was realised

to be remote, the smoke arising from smouldering dust can be very troublesome and might even cause nervous passengers to show signs of panic.

In March of 1938, London Transport's engineers tried out an entirely new method of sound absorption. They installed screens of perforated asbestos wood erected from the rail level of the tubes and rising to the level of the floor of the railway cars. Between this asbestos



End view of channel between the panels and the side of the tube.

boarding and the tunnel lining foamed furnace slag was packed. The screen was then finished off with a top of reinforced concrete slab. The asbestos boarding is being supplied by the Turners Asbestos Cement Company, a branch of Messrs. Turner Newall. The standard sheet is 7 ft. long, 3/16 inch thick and varies in width from 1 ft. 3 in. to 1 ft. 6 in. The Board is at present constructing a mile of these screens and outside firms are constructing 5 1/2 miles of screens. For these 6 1/2 miles

of work 9 715 sheets of perforated asbestos wood will be required.

The great advantage of this comparatively new material is that it is the most fire-resisting building board available. Unlike mattresses of fibrous asbestos, the screens of asbestos wood collect very little dust. To prevent the accumulation of even this small amount, the engineers are planning to vacuum clean all the tunnels at short intervals with specially designed industrial cleaners.

Asbestos wood has been very aptly described as « the building sheet that will not burn ». It is composed almost entirely of pure asbestos fiber, the fine silk-like treads of which have been subjected to a complex process of interlocking during manufacture. Unlike many fibrous insulating boards, asbestos wood is immune to rot or damp, unaffected by climatic change, and completely proof

against vermin. It can be handled very easily and quickly with ordinary carpenter's tools.

By installing these screens a reduction in noise of 20 per cent is being obtained over the short distance so far treated between Warren Street and Tottenham Court Road. Further south between Waterloo Station and Kensington higher screens are being installed. They are 3 ft. 2 in. high instead of 1 ft. 3 in. and reach just up to the carriage windows. Comparison between the two types of screens is now being carried on but results are not so far available.

Considerable improvements have been made with the rolling stock which has been re-designed not only from the viewpoint of increased comfort, but also with the idea of reducing noise. Asbestos blankets have been installed in the floors of coaches and similar ones



Packing and leveling the foam slag behind the perforated asbestos wood panels.

placed behind the side paneling and roof. Improvement in traction equipment has been made and also arrangements for reducing noise from brake gear, couplings and other attachments. Open type cars have been scrapped and new ones introduced with push-button doors operated by passengers. When the train is traveling underground these push-buttons do not operate and all doors work from controls looked after by the guards. They come into action, however, when the train is traveling out in the open. To prevent the entry of extraneous noises all the new rolling stock is being equipped with thicker glass window panels and special armoured glass for the sliding doors. The replacement of the old cane seating by moquette upholstery also tends to improve conditions as this material has useful sound absorption properties and is preferable to leather, or treated fabrics.

Meanwhile the track has continued to receive attention. Research on the best type of joint has borne useful results and the permanent way department is now using a scarfed joint which is really a kind of dove-tailing of the two rails and so designed that the minimum of jolt or vibration is caused during service.

There are two methods of welding, flash butt and thermit. To test the prac-

ticability of the use of the flash butt process on the underground railways, five 60 ft. rails were welded together, a total length of 300 ft., weighing 4 1/4 tons, and this mounted on a special train of flat wagons, was taken through the tunnel to a point where it was laid to replace old rails.

The Board has purchased two flash butt welding plants, one located in a fully equipped welding shop at the Main Civil Engineering depot, the other being mobile and mounted in two specially constructed wagons. Both plants can hold running rails weighing 95 lb. per yard, and conduction rails weighing 150 lb. per yard. The mobile plant can be taken from one depot to another and is used principally in connection with the equipment of new lines. As the rails have to be welded at one of the Board's depots and then taken by train to the site, the longest length to be welded is at present 300 ft.

The work of silencing London's tubes is likely to take several years to complete, as work is only possible during four hours of the night when traffic is suspended. The methods described promise a high degree of efficiency, but the engineers in charge are by no means sure that they represent the final word and constant experiments are being undertaken to obtain improvements.

[624. 8 (75) & 625. 47 (75)]

The maintenance of movable bridges ^(*).

(Railway Engineering and Maintenance.)

The responsibility for the maintenance of movable bridges and their ap-

(*) Committee report presented to the 45th Convention of the American Railway Bridge and Building Association, (October 1938).

purtenances rests with the engineering department, and primarily with the bridge engineer. Reports of incorrect operating conditions or of the failure of any parts to function properly should be forwarded to the bridge engineer by

the engineer or supervisor directly in charge of the bridge. Matters requiring immediate attention should be reported to him directly from the field so that he can initiate appropriate action to restore normal operation as quickly as possible.

Operators must be informed.

It is imperative that the operating personnel be fully informed and thoroughly familiar with the functioning of the various devices and mechanisms provided to insure safe and efficient operation of the bridge. Their correct understanding of and familiarity with the uses of these various devices and mechanisms should be checked frequently under actual operating conditions. The operating personnel should be made to realize that the electrical equipment, for example, of the average movable bridge includes much delicate and relatively complicated apparatus that should be tested frequently. This equipment requires exact adjustment, and they should know from their experience in the handling of the bridge when adjustments are necessary.

Periodic tests required.

Where bridges are operated by gasoline engines, whether equipped with the old « make and break » or a self-starter, the units should be tested at definite intervals to keep them in condition for service. Where they are used infrequently, engines should be operated at regular intervals to keep the batteries charged. Where small battery-charging units are available, the intervals between tests of the engines may be increased.

The operating personnel should be made to understand that the operating machinery will not serve as a brake to stop over-travel of the movable span. Unless this is stressed frequently and forcefully, the operators are liable to adopt the practice of reversing the machinery to stop the span swing and

avoid over-travel, causing excessive wear and possibly damage. Invariably, tests of the operations of movable bridges are made under the most favorable conditions, that is, in daylight and fair weather. Unless these tests are also made to cover the unusual conditions, complete protection is not assured. The correct use of the hand brake, the electrical brake and the emergency brake should be fully understood. This requires that all tests should be carried to the point where the emergency brake functions. Tests of the air buffers and all other emergency devices should be conducted in the same manner.

Frequent and complete tests of all of the facilities and protective devices on each movable bridge is good assurance against serious trouble. The frequency of inspections and service tests must be suited to the duty and age of the bridge. Such inspections and tests are primarily a mechanic's job or the work of a man having mechanical sense. The organization of the operating personnel must be such that supervisory officers can get at the cause of failures and effectively set up ways to eliminate them.

Substructures.

Problems relating to the maintenance of the substructures of movable bridges will be given only general consideration in this report. It is self-evident that the substructures of movable bridges must be substantial and adequate to meet fully the requirements imposed upon them, and that they must be maintained in good condition at all times. Bearing areas supporting the superstructure must be true to surface and to grade, and must be capable of withstanding the shock loads that come upon them without undue displacement. The materials used in making repairs to substructures must be of a kind that will act without a tendency to flow, break up, be abraded by the action of the moving bridge part, or be affected adversely by

the natural elements or by the loads which pass over the bridge.

One railroad makes the following report of repair work done on an old swing bridge substructure to meet the more exacting requirements of present-day structures. The work was done in 1937 on a 230-ft., two-track through riveted truss swing bridge which carries a large volume of rail traffic, consisting of switching movements and high-speed passenger trains. The bridge was built in 1898 and the machinery was remodeled in 1908. Crowding of the masonry abutments had continued for a long time, probably starting soon after the bridge was built. Abutment anchorage had been installed years ago, but it was not very effective. The backwalls had been chipped to clear the ends of the movable span as this movement continued. The end bearings and latch castings has been moved a number of times until they were partly off the bridge seats and on masonry inadequate to carry the loads.

The work done in 1937 consisted of replacing the bridge seats and backwalls with reinforced concrete blocks, and the installation of more substantial anchorage for the abutments. The anchorage at each abutment consisted of rods extending through the new bridge seat blocks, and back through the fill to steel sheet piling and treated timber blocking located about 45 ft. back of the abutment. After the bridge seats and the anchorage work were completed, additional new concrete was poured in the backwalls.

Lubrication.

The operating machinery, bearings and all moving parts of movable bridges require careful lubrication to insure ease of operation and minimum wear of surfaces in contact. Fast moving parts and bearings under heavy loads should be given special attention. The importance of lubrication demands that the

responsibility for this work be definitely fixed. It is necessary that supervising forces see to it that the work is done thoroughly. A greasing chart should be posted for the guidance of oilers at bridges where many parts require lubrication. It is good practice to make a thorough check of the oiler's work not less than twice a year, preferably in the spring and in the fall. This can be done best by a mechanic specifically assigned to inspect and make minor repairs and adjustments to the operating machinery. Costly repair work can often be avoided by close attention to the lubrication of the operating machinery.

It is essential that good grades of lubricants be used. Proper care in the selection of lubricants will make it unnecessary in many cases to change the grades of the lubricants for summer and winter lubrication. In one instance, it was reported that a grease was being used that would pack and harden in the pressure cups. When this was investigated, it proved a simple matter to select a grade that would lubricate the year around. A careful check of each lubricating problem should be made to determine the kind of lubricant to be used.

On large trunion bearings the grease grooves are relatively long. In the early fall, these grooves should be rodded and cleaned thoroughly, a light oil forced into the grooves, and the span then operated a few times to distribute the oil. Immediately following this, the grooves should be filled with grease, using a grease gun, and then the pressure cups should be put back in place. If the cups are then refilled as required, good lubrication will be assured. This procedure is more important than a change in the grade of the lubricant.

On swing bridges, close attention should be given to the cleaning and oiling of the center bearings. The center should be drained periodically, washed and refilled with new oil. The washing should be done with a light lubricating

oil, diluted with kerosene; otherwise the oil film will be washed out and the surfaces of the discs will run dry before the new oil works in and becomes effective. This will cause a bad situation, as the dry surfaces will stick and cause a noise.

Liberal lubrication of end lift wedges is also necessary. Lack of sufficient lubrication is sure to result in failure of the power unit to drive the wedges home.

Failure of a bearing to be lubricated properly may not always be caused by a faulty lubricant or by lack of attention on the part of the oiler. Bearings under heavy loads may be distorted if not supported uniformly over the entire surface, thus putting such abnormally high pressures on some areas of the bearing that the lubricant is forced to adjacent areas where pressures are not so great. Such a situation is sure to cause trouble, and, while difficult to correct, it is possible to improve the situation. The edges of grease grooves should be rounded, otherwise the sharp edges will cut the grease film from the shaft instead of spreading the grease.

Bearings under heavy loads can be equipped with special fittings, permitting the greasing to be done with a high-pressure grease gun. In one case reported, a heavy bascule bridge was equipped with 90 fittings, through which grease is forced every 24 hours. The old grease is forced out through pet cocks located at suitable points.

Care of machinery.

Bolts holding bearings to the structural supports should be kept tightened. Suitable reinforcement should be provided for bearings which cannot be held against movement, even though bolts are tight. This can be accomplished by bolting, riveting or welding short angles, or bars around the bearings to form shoulders to resist the thrust from the bearings.

Shafting should be watched to see that looseness does not develop in the bearings. Ordinarily, liners can be removed and the caps adjusted to take out looseness. Metal liners are better than fibre liners in most cases, because more accurate adjustments are possible. Where unusual looseness exists, it may be necessary to rebabbitt the bearings or to install new parts.

Bearings and shafting should be checked for alinement. Their behavior should be studied under operating conditions to insure that load conditions do not produce changes in alinement which, if not corrected, will cause unnecessary wear. Likewise, the action of machinery supports should be studied under actual operating conditions to see that they do not bend or warp, resulting in misalignment under load. This is especially important in the case of new bridges where it is essential that a thorough check be made of every machinery part to see that it is acting properly, and equally important, to make final adjustments of the bearings, shaft couplings, clutches, limit switches, worms, equalizers, and the meshing and alinement of gears.

Gears should be watched to see that they are tight on the shafts. Loose gears cause wear of the keys and the key ways, necessitating fitting offset keys or recutting key ways, or putting in larger keys. Information received concerning work done by one road states that loose gears were arc-welded to the shafts to make them secure. Where this is done, it is feasible to take the whole assembly to a machine shop for removing the weld beads in case it is necessary to renew the gears or shafts.

It is imperative that spare machinery parts be available at each bridge to replace those parts that cannot be obtained on short notice; also spare parts for anticipated renewals. Frequently, defective parts can be repaired for temporary or even regular use by welding.

The broken teeth of gears can be built up; broken shafting can be butt-welded; and shafts worn in bearings can be built up and then turned to original dimension. It is oftentimes possible to obtain gears from standard stocks, or they can be cut from standard blanks on short notice. Spur gears have been flame-cut from structural slabs and used without finishing. It is well to remember also that the « old black-smith » is still on the job and can help out in many ways.

It is often necessary to remove a succession of gears and shafts to get to a gear which has become loose and is working on the shaft, or is otherwise defective. In some instances, it will be possible to replace such a gear with a split gear after destroying the old gear to get it out of the way. This procedure makes it possible to avoid removing a lot of machinery to tighten or replace the old gear.

The adjustment of electrical brakes on motor shafts, of limit switches on wedge drives and on rail lifts, and of emergency and hand brakes should be watched closely in order to keep these units in the best of condition.

Auxiliary power.

The auxiliary or stand-by power units should be maintained at maximum efficiency at all times. The operation of these units should be checked at prescribed intervals to make certain that they will be available when needed, and also to insure that the operating personnel will be familiar at all times with the use of these facilities.

In a test of an air motor at an important bridge, water resulting from air condensation froze in the motor. The installation of a device to introduce alcohol into the air line at the motor cleared up the trouble.

In a test of the hand-power mechanism on a very important bridge, it was found that the capstan and capstan

shafts had rusted in the bearings and could not be used until several hours had been spent putting them in shape. In another case, it developed that the rack pinion had moved out of mesh with the rack. As a result, the hand-power unit could not be used until this condition was remedied. In still another case, it was found that the clutch that put the hand-power machinery in mesh with the turning machinery could not be used without being held in place by timber blocking. A thorough test of a gasoline auxiliary power unit at another bridge developed the fact that the adjustment of the control mechanism was such that two men would be required to operate the bridge where only one was ordinarily available. Proper adjustment of the control mechanism remedied this condition.

It seems fair to state that the auxiliary power units at movable bridges require more thorough inspection by the supervisory forces than do the primary power units, because they are more likely to be overlooked.

Swing spans.

There does not seem to be any reason for differentiating between center-bearing and rim-bearing types of swing bridges, or between the various types of end lift and end rail mechanisms, since the maintenance problems appear to be very much the same. There is a great deal of similarity in the defects which occur in each of these types.

It is essential that the track and rack sections be watched closely. Openings at the joints of the rack sections indicate that movements of these parts has occurred, resulting in wear and loosening of the bolts anchoring them to the track sections. This condition may be the result of the stretching or loosening of the bolts in the anchorage of the track, which causes loosening of the bolts of the track sections, permitting these sections to move, with the result that even-

tually the joints between the sections will be open. This can be corrected by tightening the anchor bolts of the track sections and cleaning and refitting the rack sections. It may be necessary to ream the holes in the rack sections and to substitute larger bolts. In cases where this will not correct the condition, thin strips of copper may be inserted in the openings before the final tightening of the rack bolts. Sheared or otherwise defective tap bolts in the tread sections should be replaced with tight-fit bolts. To do this requires skilled workmanship.

Uneven wear of the rollers, caused generally by the center pier being out of level, should be corrected by removing the rollers and refinishing them to true conical surfaces, with the apex at the center of the ring. The area under the turntable track on the center pier should be bush-hammered to a true level surface. Shims should be placed under the track sections and between the upper tread sections and the drum flange to keep the spider, radial rods and other parts in the same relative positions as though the rollers were full size.

Failure of some of the rollers to take bearing throughout the arc of the swing necessitates adjustment in their position on the radial rods. This change may result in causing the rollers to creep. Where power conductors, trolley and collectors are attached to the radial rods, creeping of the rollers creates a nuisance; otherwise, the action is of little consequence. The overhead collector arrangement, with towers at the ends of the center pier protection for carrying signal and power cables, is more satisfactory and more easily maintained than bringing power to the operator's house from the center pier, up through the turntable machinery.

Failure of a span to revolve on its true pivot throughout the arc of swing because of too much clearance between the discs and the walls of the center

casting can be corrected by providing a guard ring and ring filler to center the top casting accurately in the chamber of the center casting.

Rack pinion shafts loose in bearings, improper mesh between rack pinion and rack, shrouded rack pinions riding racks, and rack pinions loose on the shafts can be corrected by careful workmanship, proper attention, and careful adjustment of the moving parts.

Improper design or unforeseen operating conditions often make it necessary to reinforce machinery struts, rack pinion bearing supports, and other structural details to which the turning machinery is attached. Failure to keep machinery in proper adjustment will necessitate extensive repairs, and the renewal and strengthening of supports, including the reaming of holes to permit the use of larger bolts at points where the machinery is attached to the supporting members. Broken rack pinion shafts and machinery shafts generally indicate poor alinement or adjustment in the bearings, and call for the correction of the cause of failure and the replacement of defective parts with parts of improved design or of a better grade of material.

The adjustment of the end-lift mechanism should be such that the bearings will not lift clear at one end when the opposite end of the span is loaded. This is especially important where end-lift wedges are used. The jar and vibration of traffic cause movement of the wedge arms, and the cranks are forced off center. Then when the wedges come down to bearing, they move out of position by backing up the machinery, leaving the ends of the span without firm support, constituting a very dangerous condition. Where signal locking devices are connected to the wedge mechanism, any movement of the wedges under traffic results in damage to these devices, making repairs necessary before they can be made to function properly. This condi-

tion can be corrected by the installation of brakes on the end-lift power units, or vertical locking can be provided at the head of each end-lift wedge.

The use of brakes, stop blocks or other devices to control the movement of end-lift and rail-lift machinery is necessary to insure against overtravel of this machinery and consequent damage to moving parts. The use of these devices makes it possible to maintain close adjustments of the mechanisms which they control, and permits their more rapid operation.

Smooth, safe train operation over movable bridges at moderate speeds can be had only when the end rails of such bridges are properly maintained and kept in good adjustment. Positive anchorage of the running rails on movable bridges is desirable. The use of rail anti-creepers or other anchoring devices at the ends of the approaches to a movable bridge is necessary to keep the track rails from creeping toward the bridge and fouling the rails on the movable span, or to prevent movement in the opposite direction, with consequent battering of the rail ends at the open joints produced.

The end rails must be kept in good surface by careful adjustment of the rail plates to insure against breakage and excessive wear of the rails. The movable rails must be supported uniformly throughout their entire length; otherwise, they will deflect at points of poor support and excessive up and down movement of the rail will occur. The ties should be uniform in size and spaced evenly. The rail plates at the heels of lift rails should be given special attention to see that all bolts are kept tight and that the joints are shimmed whenever looseness is noticed. Bad riding joints are greatly improved by moving the rail anchorage from points adjacent to the end timbers to points near the centers of the rails. In a case noted recently, a part of this anchorage consist-

ed of wide plates which extended over three ties. These plates did not cut into the ties as deeply as the tie plates back of them, which resulted in the ends of the rails being lifted as each car truck approached the anchorage, and then being slapped down as the track passed over the joint.

Bascule spans.

The maintenance problems in connection with bascule bridges are not essentially different from those for swing bridges. Moving parts require more careful adjustments; brakes, limit switches and other control devices must be timed accurately and kept in first-class condition.

The maintenance problems are simplified if the structural supports for the bearings of the operating shafts and gears and for the other machinery bearings are substantially built to withstand the shocks and jars inherent in the operation of this type of bridge. The design of adequate reinforcement for these supports is limited by the practicability of carrying out the field work because of their inaccessibility. By way of illustration, mention is made of such typical repairs as the anchorage of the machinery girders to the tower girders; the reinforcement of the machinery supports on top of the hanger posts; repairs to the tower posts and trunnion hangers at points where the operating shaft bearings are attached; the alinement of the operating strut guide; and the adjustment of the trunnion bearings.

The rack sections in the operating struts should be watched for signs of loosening and for broken teeth. A defective tooth in a rack section adjacent to the operating pinion gear can be corrected temporarily by interchanging the defective section with a section at the trunnion end of the strut.

Pneumatic emergency brakes are generally used on heavy bascule bridges for the control of the moving span when

operating under unusual conditions. These brakes are important adjuncts to the operating machinery and require unusual attention to keep them in working order.

A pneumatic buffer is an essential feature of the heavier bascule spans and should be kept in operating condition at all times. There are definite limits to the effectiveness of air buffers, and they afford no assurance against damage to the bridge resulting from careless operation. End locks should be maintained in good condition, especially on double-leaf spans.

It is necessary to give close attention to the counterbalancing of bascule bridges. There are limitations to the additional weight that can be added to bascule bridges, as for the reinforcement of structural parts or increased weights of track and other materials. Maintenance of the counterweight unit is important.

Unbalanced counterweight loads increase the hazards when bridges are being operated, and also cause excessive wear on operating machinery which may result in increased power costs.

Vertical lift bridges.

The maintenance problems on lift bridges are similar in many respects to those on swing and bascule bridges. The repair and adjustment of the lift machinery require the same care as for machinery on other types of movable bridges, although this type of bridge permits the assembly of the machinery in a very compact unit, with fewer parts to be looked after.

The operating cables should be inspected closely for wear of the wire strands. The liberal use of good cable dressing will protect the cables from deterioration and wear. The counterweight sheaves, operating drums, and guide sheaves should be checked carefully for alinement to insure minimum wear on the operating cables. Where the counterweight cables are separate

from the up-and-down haul cables, all of them should be watched closely and adjusted as necessary to keep the bridge correctly balanced and centered in the guides on the tower posts to insure operation without unnecessary friction and wear in the guides and the proper seating of the span on its bearings.

It should scarcely be necessary to caution against the method used a few years ago of forcing the full seating of a lift bridge when one end of the bridge cannot be seated by the operator.

Bridge and rail joints.

Devices for bridging the rail gaps at the ends of movable bridges vary in design to accommodate the particular class of traffic over the bridge. Frequently they must be maintained for speeds as high as 70 miles an hour. In most cases the rails extend beyond the ends of the movable spans and must be firmly supported to minimize movement up and down and to eliminate the hammer blow of the moving wheels as each wheel passes over the joint.

The following are some of the more common types of joints :

(A) Rails with square ends, with open gaps between them.

(B) Rails with mitered ends which overlap and form a continuous wheel bearing over the joint.

(C) Rails, one of which is mitered and the other bent outward so the web will be parallel with the mitered rail. The head and base on the bent end are cut off flush with the web. The two ends overlap.

(D) Rails with their ends bent and with the head and base of each cut flush, with its web on the side adjacent to the other rail so the two rails will overlap. The inner projecting portion of the head of one rail is planed to the gage line.

(E) Rails with square ends and with open gaps bridged by a bar or tongue sliding in contact with the webs and

heads of the rails and fixed guides on the outer sides of the rails. The gaps are at the ends of the movable span, and the ends of both rails are rigidly anchored.

(F) Rails with the ends mitered to overlap a small amount, the gap extending beyond the ends of the movable span and rail locks being bolted to the ends of the rails of the movable span and straddling the ends of the fixed rails. The inside lock is formed with a flange-way, and the outside lock bridges the gap.

Types A, B, C and D are applicable particularly to swing and lift bridges; Type E to all movable bridges; and Type F to bascule bridges only.

Types A, B, C, and D present many maintenance problems on swing bridges because the shore ends must be lifted to clear the fixed rails when the bridge is opened; hence, it is evident, these rails cannot be fastened down rigidly through any part of their lengths.

Types E and F present two major maintenance problems. The first consists of holding the rail locks and the slide bars in position against the rails, and the second consists of maintaining the correct surface of these devices with respect to the running rails so that they will actually bridge the gaps and afford smooth riding over the joints. These devices should be maintained about $1/8$ in. higher than the rails at the gap, particularly if train speeds are at all high. They should be slightly below the rails at the ends and rounded from the ends to the center. The top surface should be beveled at right angles to the rail to the taper of car wheels, to afford increased wheel tread bearing surface.

The time limitation for presenting this report has made it necessary to with-

hold from the report herewith many interesting examples of bridge failures and methods of repair. All of these, however, will appear in the Proceedings of the association when published.

Discussion.

Discussion of this report centered largely around the question of responsibility for the maintenance of the various units on movable bridges. It was cited that on some roads the bridge operator reports to some officer in the transportation department, while on others he is a signal department employee and on still others, he reports to the supervisor of bridges and buildings. It was brought out that similar variations occur in the methods of maintenance, on some roads the turning machinery and rail lifts being maintained by the mechanical department and on others by the bridge and building forces. On all roads the electrical equipment and signaling equipment are maintained by the respective departments having jurisdiction, while the bridge and building department maintains the bridge itself.

Speed restrictions also were considered and it was brought out that these vary from six miles an hour to no restrictions. Certain old bridges have rail locks that are not safe for high speeds and the roads having such construction place severe speed restrictions over them as a precaution.

On long spans on north-and-south lines it sometimes occurs that during the morning hours, the easterly truss expands much more rapidly than the westerly truss, sometimes causing trouble in locking the bridge. To prevent this, the Louisville & Nashville has put a galvanized sun shade on one side of a long span to prevent its heating up too rapidly in the morning.

Northern Pacific builds turntables 135 ft. long.

(*Railway Age.*)

Three structures of the continuous type, installed in the last two years, are believed to be the longest ever constructed.

In 1936 the Northern Pacific placed some new locomotives in operation between Livingston, Mont., and Missoula, which were longer than any previously in use, and which necessitated the replacing of the existing turntables with longer ones. These locomotives, which are of the Mallet type, have a wheel base of 113 ft. 8 in. and an over-all length of 127 ft. 1 in. In rebuilding the turntables to serve these locomotives, it was decided to build them 135 ft. long to allow for still further increase in locomotive lengths in the future, since the turntables which required extension or replacement had been in service only a few years.

The first turntable to be rebuilt was at Livingston, Mont. The table at this point, which was installed in 1923, was a 100-ft. turntable of the continuous deck

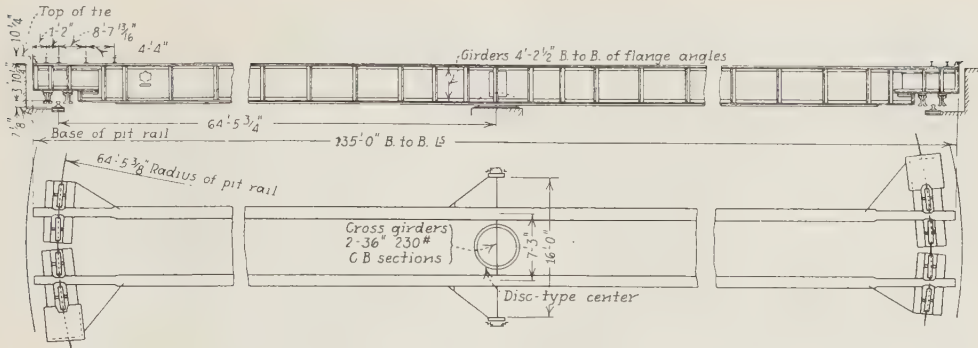
girder type with a disc center and end trucks fitted with phosphor-bronze bearings. This table was remodeled in 1936 by installing a new pair of girders 135 ft. long, which were designed to fit the old center, and to which the end trucks from the existing table were moved after being fitted with roller bearings. A year later it was decided to replace the 85-ft. turntables at Pasco, Wash., and Parkwater, with new turntables 135 ft. long in order that the new locomotives might be operated in the territory between these two points.

Designed for 592-ton engines.

These new turntables, which were designed for a 592-ton locomotive having a 2-8-8-4 wheel arrangement, are of the continuous type and have two girders of uniform section with the usual



General view of the 135-ft. continuous-type turntable installed at Parkwater, Wash.

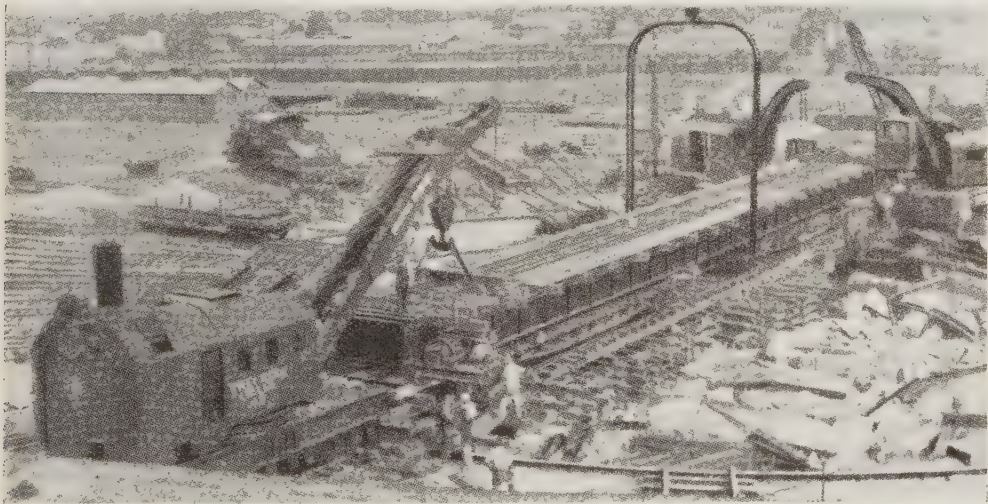


Elevation of and horizontal section through the new 135-ft. tables installed by the Northern Pacific, showing girder dimensions and arrangement.

type cross bracing. The girders are of a uniform height of 4 ft. 2 1/2 in., measured from back to back of flange angles and are supported at the center by cross girders consisting of two 36-in. 230-lb. C. B. sections. The turntable center under the cross girders is provided with a grade A bronze disc 25 in. in diameter and 1 3/4 in. thick, with grooves on the bottom which are supplied with oil by two pipes extending to the deck.

Under each end of the turntable are

four rolled steel car wheels without flanges, 33 in. in diameter. The axles of these wheels are supported in roller bearings, and the bearings are connected by 2 1/4-in. bolts to two built-up beams which are fastened to the underside of the turntable girders. Each wheel is so mounted and adjusted by means of shims that its axle is radial to the center of the turntable. Tractive power, which is furnished by two 25-h.p. electric motors mounted at diagonal corners on each end of the



Moving the new 135-ft. table into place at Paseo, over a cribbed-up track.

turntable, is transmitted to one wheel at each end by means of two sets of reducing gears. The motors use 3 phase, 60-cycle, 220-volt alternating current, run at a speed of from 900 to 865 r.p.m. at full load, and are connected to their source of power by means of an overhead collector at the center of the turntable. An operator's cab also is provided at one end of the turntable.

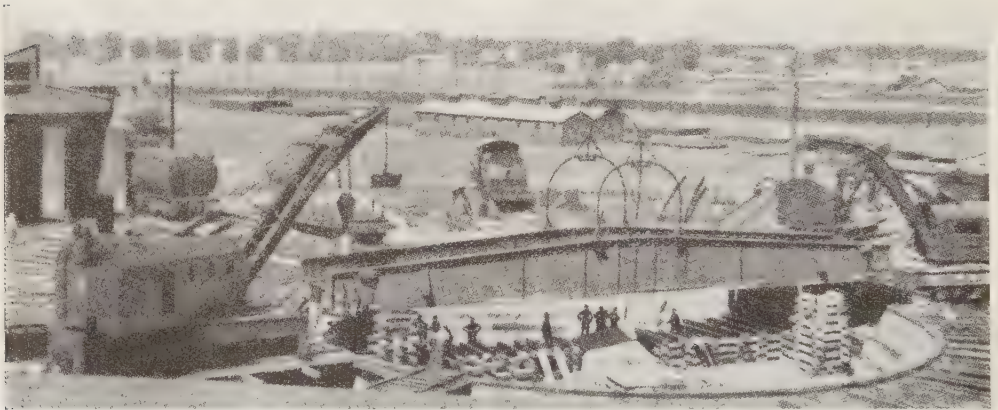
Circle rail designed for 256-ton load.

The circle rail, which is of 131-lb. section, rests on steel plates $1 \frac{3}{8}$ in. thick and 14 in. by 15 in. in area, which bear directly on a concrete pit wall of standard construction. Anchor bolts

serted, and on the pit back wall short sections of 8-in. steel H beams are placed along the back wall for support of the approaching tracks at the edge of the pit. The H beams, which are of 37.7-lb. section, are bolted to the top of the back wall with bolts set in the concrete and are also bolted to the approach rails, all of which are of 85-lb. section adjoining the turntable. The approach rails, are so anchored that they expand away from the table.

Extensive preparations.

In the installation of the new turntables at Pasco and Parkwater, the oper-



The old 85-ft. turntable at Pasco being removed. — Note cribbing in place beneath.

$1 \frac{1}{4}$ -in. thick, which are set in the concrete of the pit wall, extend through the bearing plates and hold the circle rail in place by means of specially designed, adjustable rail clips which are fastened to the anchor bolts. The pit wall which supports the circle rail is designed for a load of 256 tons on the circle rail.

The deck of the turntable is composed of bridge ties which rest directly upon the turntable girders and the rails on the turntable are of 100-lb. section. At each end of the deck three steel ties are in-

ation is described as it was carried out at Pasco, and is more or less typical of the other installation. One of the preliminary steps was to excavate and place on falsework nearly all of the approaching tracks between the old and new pit walls, this being done while the new pit wall was being constructed. The new pit wall was completed, including the installation of the circle rail, but the old pit wall was not disturbed until the turntables were being changed. The new turntable was completely assembled on

two flat cars, including ties, rails, overhead collector frame, end trucks, cab, wiring, etc. A pre-cast reinforced concrete block for the top of the center pier was also ready.

Installation.

Three wrecking cranes were used in changing the turntables, two being located at one end and one at the other. The two cranes at one end were placed on each side of a middle or working track so as to leave it clear between them. The first step was to lift the old 85-ft. turntable. A track on cribbing was then laid across the pit under the old table, connecting with the working track, and flat cars were shoved in over the old pit. The old turntable was then lowered on the flat cars and taken away. During this time, men had been busy demolishing the old pit wall and removing falsework from under the approach tracks.

As soon as the old turntable was out of the way, the top of the old concrete pier in the center was cut down to the proper elevation, and the precast concrete block was placed on top of the center pier with a locomotive crane. The flat cars sup-

porting the new turntable were then pushed out over the pit on the track on the cribbing and the new turntable was lifted clear of the cars, which were then withdrawn. The temporary track and cribbing across the pit were then removed, and the pit was cleared of falsework, timbers, and the remains of the old pit wall. The new turntable was then lowered into position.

After the turntable was placed in operation, it was found that in some cases the new locomotives would force the table out of line with the approach track when being moved on or off the turntable. The alinement of the approach tracks was found to be at fault and they were relined to provide a minimum of 58 ft. of tangent track adjacent to the pit wall.

The motors used for these turntables were a product of the Westinghouse Electric & Manufacturing Company and the roller bearings used for the end trucks were Hyatt bearings. The assembly and installation were completed by the Northern Pacific bridge and building forces under the general direction of B. Blum, chief engineer, and of the late M. F. Clements, engineer of bridges.

English 1000-B.H.P. vee-type high-speed diesel engine (Paxman-Ricardo).

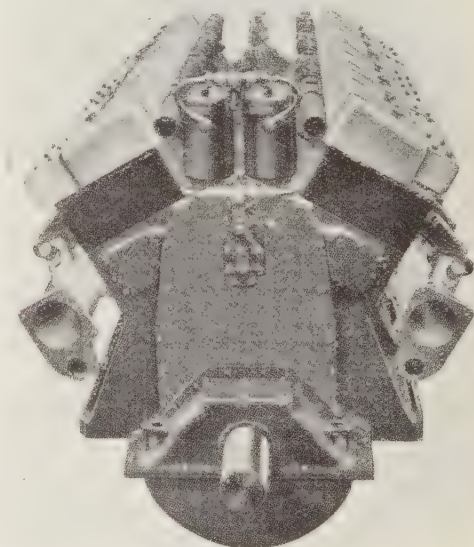
(Diesel Railway Traction, Supplement to The Railway Gazette.)

Hitherto the largest high-speed engine, say over 1 200 r. p. m., suitable for rail traction work has had an output of 600 to 650 B.H.P. when supercharged, but a tremendous step forward has been made in this field by the introduction of an engine with a maximum output of 1 000 B.H.P. unsupercharged at 1 750 r. p. m., by Davey, Paxman & Co. (Colchester) Ltd. Although designed originally for application to marine propulsion where the installation had to be made in very light hulls, the weight and bulk characteristics and the engine interior accessibility are of the order required for rail traction service. Indeed, in the weight direction, a reduction of over 30 per cent. in the specific weight compared with any engine actually in railway service has been achieved, for in the dry condition and without fly-wheel the engine scales only 5 3/4 lb. per B.H.P. when a light alloy crankcase is used.

Range of vee engines.

This new 16-cylinder vee engine is the highest development of the Paxman-Ricardo RB range now comprising 8-, 12-, and 16-cylinder engines, all with a standard cylinder size of 7 in. bore by 7 3/4 in. stroke. For convenience, the outputs and weights of all are given in the accompanying table. At the top output the piston speed is 2 260 ft. per min. and the m.e.p. 95 lb. per sq. in., and as the mechanical efficiency of the engine at full load and speed is in the neighbourhood of 75 per cent., the mean indicated pressure is 127 lb. per sq. in. Actually, on test, mean *effective* pressu-

res of 131 lb. per sq. in. at 1 000 r. p. m. and 126 lb. per sq. in. at 1 500 r. p. m. have been obtained, and if a mechanical efficiency of 78 to 79 per cent. at 1 500 r. p. m. is assumed, the mean indicated pressure at that speed would be about 160 lb. per sq. in.; all these figures were obtained without supercharging, which means that the normal useful maximum service output of the engine may yet be increased from 800 B.H.P. at 1 500 r.p.m. to something like 1 100 B.H.P. at the same speed and without any increase in the cylinder maximum pressure. The compression ratio is 15.2 to 1, the compression pressure about 550 lb. per sq. in., and the maximum combustion pressure



End view of Paxman vee engine.

about 850 lb. per sq. in. With a piston-swept volume of 78 litres, the output per litre is a maximum of 12.8 B.H.P. at 1 750 r. p. m. It is claimed that at all loads up to 1 000 B.H.P. the exhaust is invisible. We understand that when supercharged to a pressure of 21 lb. per sq. in. absolute operation at 1 750 r. p. m. can be conducted with a mean effective pressure of 150 lb. per sq. in.

It was decided in the design stage that, as the engine would frequently be used in hulls or on bases with some flexibility, it should be stiff enough to absorb its own internal reactions without outside support, and to permit of slight relative movement between the engine and the seating a semi-flexible mounting of the Silentbloc type was considered as a standard. To carry these Silentbloc bushings as far apart as

necessary to remove the water from the jackets or disturb any part of the valve gear when pistons or connecting rods are removed.

Ricardo heads.

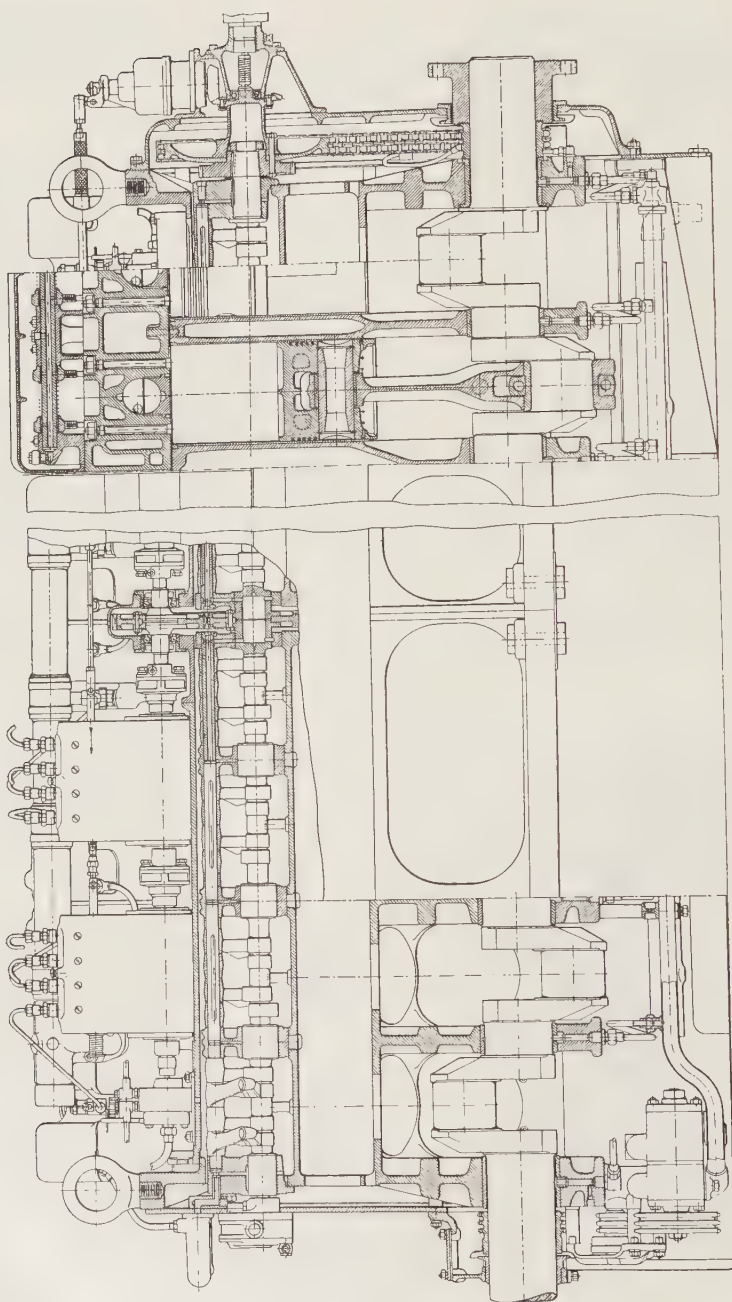
Incorporated in the cylinder heads are Ricardo Comet Mark III combustion chambers (see issue of *Diesel Railway Traction* for October 29, 1937). This particular form of air cell was developed from the earlier Ricardo heads in order to gain an improvement in thermal efficiency and thus counteract to some extent the fuel oil tax. Approximately half the total clearance volume is located in the spherical air cell and about half in a slight depression in the piston top and in the clearance between the piston crown and the underside of the cylinder head. The efficient combustion

Paxman-Ricardo vee engine, powers and weights.

Type No.	No. of cyls.	Cyl. bore and stroke, in.	B. H. P.				Light weight, lb.			
			At 1 000 r.p.m.	At 1 250 r.p.m.	At 1 500 r.p.m.	At 1 750 r.p.m.	Cast iron construction.	Light alloy construction (standard).	Light alloy construction (special).	Flywheel weight (extra), lb.
8 VRB	8	by 7 in.	265	335	400	500	5 000	3 000	2 700	440
12 VRB	12	7 3/4 in.	400	500	600	750	6 700	4 350	3 740	440
16 VRB	16	7 3/4 in.	535	665	800	1 000	8 600	5 600	4 860	440

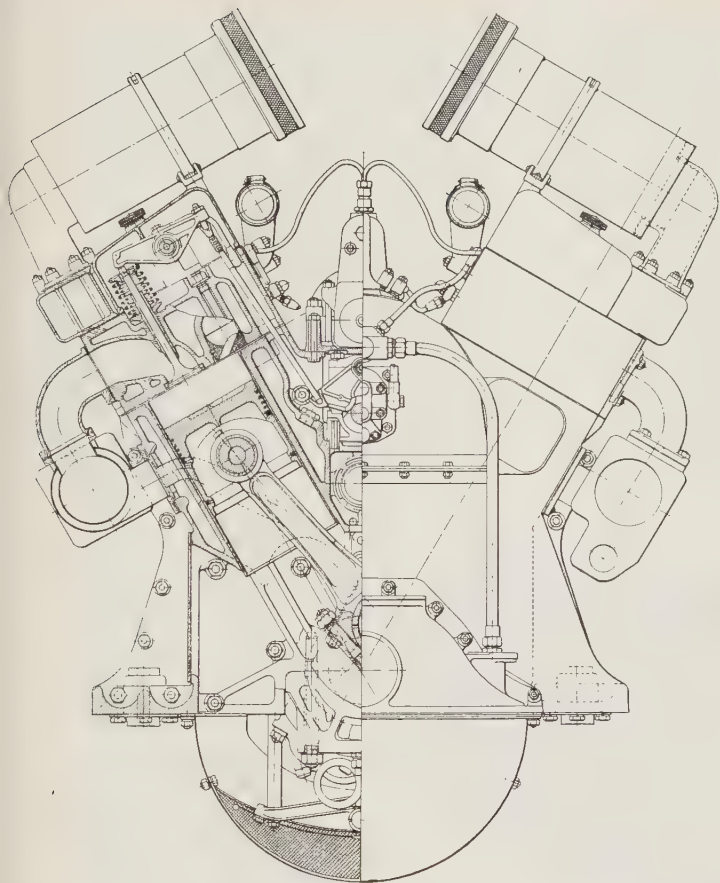
possible, and thus ensure steadiness, a wide and deep flange is provided along each side of the engine, and this also gives extreme lateral stiffness. For easy servicing of the engine, either in a yacht or in a railcar or locomotive, the engine is arranged so that the pistons and double connecting rods can be removed through large doors in the crankcase. Such a layout also improves the accessibility of the main bearings. It is not ne-

range provided by this type of head has allowed of the full speed range from idling at 300 r. p. m. to full load at 1 750 r. p. m. to be brought under the control of a single fuel lever, without any advance or retard mechanism. The use of this form of combustion chamber enables the maximum gas pressure to be kept nearly constant over a wide range of load, and allows of a low injector pressure.



Longitudinal section of Paxman-Ricardo 16-cylinder vee engine.

This engine develops a maximum of 1000 b.h.p. at 1750 r.p.m. in 16 cylinders, 7-in. bore by 7 3/4 in. stroke. When built to light alloy construction, the weight is less than 6 lb. per b.h.p. The crankshaft has a diameter of 4 1/8 in., and is made of 55-ton heat-treated nickel-chrome steel. The connecting rods are of 40-ton steel, and the motion of one rod end relative to that of its opposite number is purely oscillating; the big-end bearing pressure is about 2,500 lb. per sq. in. without making a deduction for the inertia forces. The plain rods weigh 8 lb., and are 16 in. long. Dry-type liners, 1 8 in. thick, are inserted in the cylinder block, and weigh 10 lb. each. Each cylinder head contains one inlet and one exhaust valve, but the inlet valves are considerably larger than the exhaust, in order to give the highest possible volumetric efficiency.



Cross-section of the Paxman-Ricardo vee engine designed for running up to 1750-r.p.m. An interesting point in the design is the Y-alloy piston arrangement. The pistons are provided with high-expansion cast iron inserts, which carry the top pressure ring. The insert serves to resist the hammering and sliding effects of the top ring in its groove, and to lower the temperature of that ring. For high outputs and speeds it has been found advantageous to make the pressure rings of taper section, as by doing this it is possible to prevent ring sticking. A vertical clearance of 0.001 to 0.0015 in. is given, and the angle of taper is greatest for the highest outputs.

Engine construction.

The 16 cylinders are arranged in two banks of eight with an included angle of 60 deg.; in order to keep down the overall length of the engine to a minimum, simplify the main frame casting, and at the same time provide ample bearing surfaces, the cylinders are exactly opposite to one another, and the connecting rods of one bank are forked over those of the other, which incidentally gives equal strokes to the pistons of both banks. The cylinder block and crankcase above the crankshaft centre line are combined in an integral casting

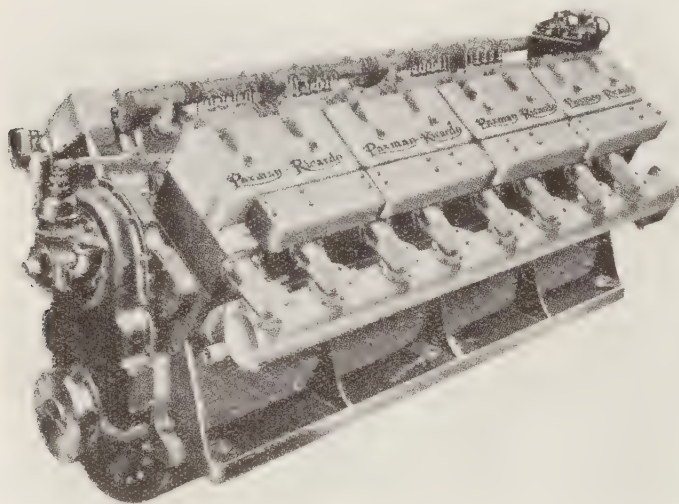
of Hiduminium RR. 50 aluminium alloy, but cast iron can be used where weight limitations are not severe. This main casting carries the crankshaft through nine underslung bearings with caps of heat-treated Hiduminium RR. 56 forgings. The lower part of the crank chamber is in the form of a separate light-weight sump.

Hiduminium RR. 50 light alloy is used for the cylinder heads, which are cast in pairs for the eight-cylinder and 16-cylinder engines, and in threes for the 12-cylinder model. They are machined to limit gauges and fitted to the top of the cylinder block by studs. In each cy-

linder head is carried one inlet and one exhaust valve, and the whole 32 are driven by one chain driven camshaft located in the vee between the two banks of cylinders. As it is not necessary to remove the cylinder heads to get access to the pistons, Stellite inserts have been used in the cylinder heads and the valve seats have been Stellite, so the grinding of the valves and seats should not be necessary except after very long intervals. The hardened cams are integral with the camshaft and drive the valves through pressure-lubricated rockers and short ball-ended Duralumin push rods. The overhead valve gear is entirely enclosed in magnesium alloy oil-tight and dust-tight covers.

pumps to each side are driven in tandem. The fuel pressure at an engine speed of 1 500 r. p. m. is about 3 000 lb. per sq. in., and at 1 000 r. p. m. about 2 500 lb. per sq. in.

Dry-type cylinder liners of pearlitic cast iron are inserted in the cylinder block, and are accurately honed and interchangeable. In them run Y-alloy pistons fitted with taper section rings which obviate any tendency to sticking; four pressure and three scraper rings are used. The uppermost pressure rings are fitted into special high-expansion iron inserts cast into the piston to resist wear in the ring grooves. Fully-floating casehardened nickel steel hollow-bored gudgeon pins transmit the



Paxman-Ricardo 16-cylinder light-weight engine as designed for quick-running marine and railway applications. At the maximum unsupercharged output of 1 000 b.h.p., the speed is 1 750 r.p.m., but a maximum supercharged output 50 per cent. in excess of this figure, at the same rotational speed, is believed to be practicable.

Four special light-weight single-block four-ram C. A. V.-Bosch fuel pumps supply the fuel to single-hole self-cleaning pintle-type atomisers located in the Comet air cells, and which have a spring set to 1 500 lb. per sq. in. The fuel pumps are located in the vee between the cylinders, but above the main camshaft; the drive is taken from this camshaft at the engine centre, and the two

drive through chill-cast phosphor-bronze floating bushes to the drop-forged I-section connecting rods, which are of 40-ton nickel steel. The big-end bearing shells for each crankpin are common to the two rods driving that pin, and the steel bushes are lined inside and outside with white metal. The crankshaft is a single forging of heat-treated nickel-chrome steel, and the

crankpins are hollow-bored. The main bearings have loose steel shells lined with anti-friction metal, and one of them acts as a thrust bearing. A 55-ton heat-treated nickel-chrome steel is used for the crankshaft when the lightest possible engine is desired.

Lubrication system.

Lubrication is completely automatic on a high-pressure system working normally at 50 lb. per sq. in. Cooled oil is forced by a pump through a filter, and then along a common rail from which leads are taken to each main bearing; a proportion of the oil to the main bearings is led through holes drilled in the crankshaft to the crankpin bearings. Oil thrown from the big ends lubricates the cylinder liners and gudgeon pins. From this high-pressure circuit oil is taken through a reducing valve to a secondary low-pressure system which feeds oil to the overhead rocker gear, camshaft, and similar parts, and the surplus oil returns to the sump by gravity through internal passages. The pumps maintaining the lubricating and governor oil systems are of the valveless gear type, and are two in number—one pressure and one scavenger.

A supply of oil is taken from the main lubricating system to provide the operating power for the patent double servo centrifugal governor, which is contrived so that a fall in lubricating oil pressure below a certain pre-determined figure brings the engine automatically back to idling speed. Moreover, the construction of the governor enables the engine speed to be varied instantly from idling to full load with only finger and thumb control, and the power on the

fuel pump is maintained irrespective of the engine speed.

Water-cooled exhaust manifolds of Birmabright light alloy are provided, and are arranged at the sides of the engine below each bank of cylinder heads. The cooling water manifolds are in the central vee, and the air induction manifolds, made of magnesium alloy, are along the outside of the cylinder head casings. An engine-driven cooling water pump is mounted at the end of the engine remote from the driving end and delivers the water from the radiator first through the exhaust manifold, then to the jackets, and *via* the cylinder heads to the outlet manifolds; the temperature control is thermostatic. Starting can be effected either electrically or by air, as desired; in the former case 24-volt current is used for the starting motor, which operates through the usual Bendix drive. When air is used it is standard practice to admit the air to the cylinders through a reducing valve set to about 400 lb. per sq. in.

Fuel consumption over the normal working range is remarkably constant, but is not unduly low, being about 0.41 lb. per B.H.P.-hr. at 1 000 B.H.P. at 1 750 r. p. m. When running at 1 600 r. p. m., the fuel consumption is below 0.405 lb. per B.H.P.-hr. for mean effective pressures between 70 and 97 lb. per sq. in., and when operating at 1 400 r. p. m. is below 0.405 lb. per B.H.P.-hr. at all m. e. p.'s between 65 and 97 lb. per sq. in. On the test bed it was proved that at these speeds the maximum cylinder pressure varied only between the limits of 790 and 830 lb. per sq. in. for mean effective pressures over the range of 70 lb. to 110 lb. per sq. in.

Davenport-Besler builds 105-ton diesel-electric switcher.

Locomotive power plant consists of four Caterpillar 190-h.p. diesel engines with electric drive to all wheels.

(Railway Age.)



Davenport-Besler 760-h.p. diesel-electric switching locomotive.

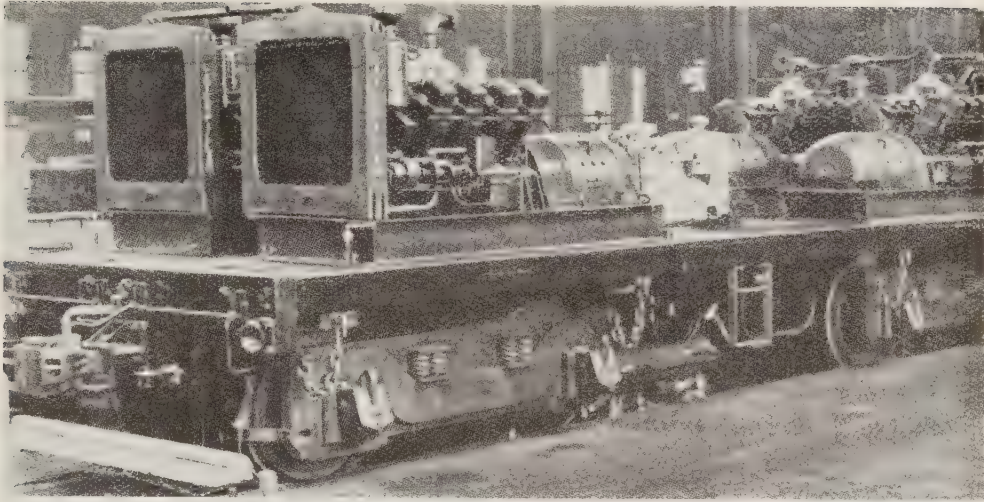
A 105-ton, 760-h.p. diesel-electric locomotive has recently been constructed by the Davenport-Besler Corporation, Davenport, Iowa, which incorporates a number of unique features of design, primarily the use of multiple diesel-electric generating units which furnish power to electric motors driving all truck wheels. In this case, four Caterpillar diesel engines, each rated at 190 h.p. and directly connected to a General Electric electric generator, supply power to four General Electric motors geared to the truck wheels.

The new Davenport-Besler switcher consists of two four-wheel motor-driven trucks which support a heavy built-up structural-steel underframe carrying the main diesel engines, main generators, auxiliary equipment, engine hoods and the engineman's cab. The

cab is centrally located, contains the necessary electrical control apparatus, instruments, brake valves and throttle controls and has an elevated cab floor to provide a large field of vision for the engineman. Engines, generators, auxiliary equipment, control apparatus and operating controls are located and arranged to permit maximum accessibility and convenience in operation.

The various component units have been selected with a view to giving long and trouble-free service with a minimum of maintenance. The locomotive has been designed to permit the most efficient operation for the various duty cycles encountered in railroad and industrial switching service.

The four main diesel engines, made by the Caterpillar Tractor Company,



The Davenport-Besler switcher in the process of construction at the Davenport Locomotive Works.

Peoria, Ill., are of the four-cycle, eight-cylinder, V-type, with 5 3/4-in. bore and 8-in. stroke and are directly connected by flexible couplings to the four main generators. These engines are carried on heavy channel sub-bases securely bolted to the underframe top plate. The same sub-bases also carry the main generators. The auxiliary engine, also made by the Caterpillar Tractor Company, has four cylinders, with 4 1/4-in. bore by 5 1/2-in. stroke. This engine drives the 5-kw. auxiliary generator which charges the battery for the operation of controls and lights. It also furnishes power for the compressor and for the blower for cooling the traction motors. The main and auxiliary engines have Burgess mufflers with the final exhaust carried out through stacks located above the engine hoods. These exhaust stacks, also aid in ventilating the engine compartments.

Cooling is by means of radiators in integral assembly with the engine. Each engine has its own radiator and fan to provide cooling air. The cooling sys-

tems of the two front engines are connected, as are also the two rear engine cooling systems.

The main driving engines are started by utilizing an auxiliary winding in the main generators, power for which is drawn from the storage battery. The auxiliary engine has an automotive starting system. Conveniently arranged switches at the engineman's position allow individual starting of each engine.

The battery is a heavy-duty 64-volt, 13-plate type, having 215 ampere-hours capacity. Headlights, on both the front and the rear, are so arranged that either can be dimmed, turned on or turned off. There is a dome light and instrument panel lights in the cab, as well as lights in the engine compartments to permit inspection. A small flashing light gives warning in case trouble develops in the power plant.

Generators, motors and blowers.

The main generators are shunt wound and so designed as to match the engine characteristics closely. They are de-

signed for railroad service and have capacity enough to transmit full engine output continuously to the traction motors. Generator cooling is by means of a built-in fan. A two-bearing shunt-wound generator, driven by the auxiliary engine, is provided for charging the battery.

The four heavy-duty railway-type traction motors are arranged for one combination of motors, with field shunting arranged for. The motors are cooled by forced ventilation from the constant-speed mechanical blower through a system of ducts, with flexible connections at the motors. Heat-treated forged gears of 16 to 68 ratio connect motors to axles. The gears operate in a bath of oil carried in heavy dust-proof gear cases. Motors have spring-cushioned suspension and are provided with safety lugs.

Features of the truck design.

The trucks are of the four-wheel motor-driven type. They are built up of rolled-steel slab frames with heavy plate bolsters, motor-suspension lugs, brake-cylinder supports, brake-hanger bosses, spring supports, side bearing supports, and center plates all welded into an integral unit. The pedestal jaws are machined and equipped with renewable spring-steel wearing shoes. Pedestal tie bars have wedge-shape lugs and are attached to pedestal frames with fitted bolts. The truck frames are supported on nested coil springs carried on double forged equalizers which are supported by the journal boxes. Detachable safety chains are applied at each corner of the trucks and fastened to the underframe. The traction motors are suspended between the axle and bolster through spring-cushioned motor nose and lugs welded to the bolster. Truck and underframe side bearings are fitted with renewable hardened wear plates.

The axles are of high-carbon forged steel and heat-treated, conforming to

A. A. R. specifications. The diameter at the motor bearing is 8 1/2 in. and at the journals 7 in. The wheels are solid rolled steel, heat treated and with machined treads and flanges conforming to A. A. R. standards. The wheel diameter at the tread is 40 in.

The journal boxes are of cast steel, suitable for 7-in. by 13-in. journals. They are fitted with A. A. R. railway-type crown brasses and end thrust blocks. Approved type dust guards and dust-excluding lids are provided.

Underframe construction.

The underframe is constructed of heavy structural-steel shapes welded and riveted to a slab steel deck plate with two heavy channels forming the center sills which, with the bolsters and properly spaced cross members, provide a structure capable of withstanding the severe shocks and stresses of heavy switching and railroad service. The bumpers are heavy steel slabs bolted to connecting angles and cast-steel brackets fastened to the underframe. Push-pole pockets are bolted to the bumpers. Body center plates are of cast steel riveted to the center sills and are lubricated.

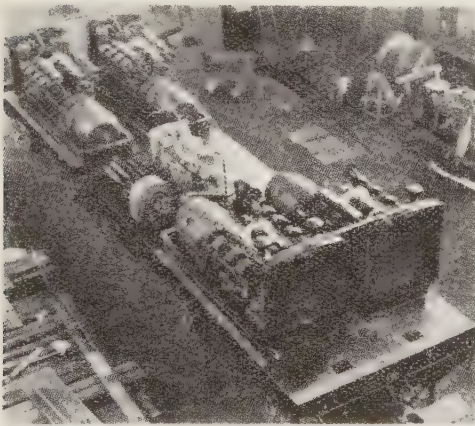
The couplers are standard A. A. R. Type-E, mounted in cast steel pockets with the supporting shelf bolted to the bumpers. The center line of the coupler is 34 1/2 in. above the rail. Provision can be made for the application of standard friction draft gear. The uncoupling device consists of forged-steel levers arranged to operate from either side of the locomotive in accordance with A. A. R. standards.

The footboards at each end of the locomotive meet the U. S. safety appliance requirements. They are equipped with step lights and also have mud-guard plates attached.

All brake rigging is carried on the truck frame, including the brake cylinders which are mounted on each side of the trucks. Rigging is of the spreader

der type with turnbuckle adjustments. Brake shoes are standard railway type with steel inserts and removable heads. A hand brake, with hand wheel 22 in. in diameter, located in the cab, is connected to the brake rigging of one truck.

Westinghouse schedule 14-EL brake equipment is used. Air reservoirs of not less than 40 000 cu. in. capacity are mounted under the main frame between the trucks. The air supply is furnished by an air compressor of not less than 80 cu. ft. per min. capacity, driven by the auxiliary engine. Dirt collectors, safety valves, and cooling pipe are installed as required.



Looking down on the main and auxiliary Caterpillar diesel-engine-generator sets on the locomotive frame before the application of the cab and engine hoods.

Heavy-duty self-cleaning sander traps and an operating valve are supplied. Four sand boxes, two at each end of the locomotive with a total capacity of approximately 16 cu. ft., are welded into the main frame. Ample size clean-out covers are placed at the bottom of each box. The sand boxes are filled from outside the locomotive. Sander pipes deliver sand to the front of the leading truck in either direction.

General construction of the superstructure.

The cab, centrally located, is of all steel construction welded and riveted together and securely anchored to the main frame. It is lined with insulation board. There is ample visibility through plate-glass windows having steel sash. Side windows are of the sliding type and have locating latches. Swinging doors, with plate-glass windows, are located at diagonally opposite corners of the cab. The elevated cab floor, of checkered steel plate, is equipped with trap doors to give access to equipment placed underneath. Steel doors are placed at each end of the cab to permit entry into the engine compartments. The cab is fitted with air-cushioned seats, upholstered arm rest, hot-water motor-blown cab heater, air-operated window wipers, and a ceiling light.

The engine hoods, of heavy steel construction, are provided with hinged doors, with suitable latches and locks, permitting access to the engines, generators and accessories for inspection and maintenance. The hoods are thoroughly ventilated through screened and baffled openings. The front of the hoods is removable so that the entire power unit can be easily removed for major repairs. A heavy grill allows entry of cooling air. Each compartment has permanent light fixtures and receptacles for inspection lights.

The fuel tank, of 350-gall. capacity, is constructed of heavy steel plates, arc-welded together. It is mounted cross-wise under the main frame. The tank has a Protectoseal filler, flame-arrestor vent, and Protectoseal sump for draining off water and sediment. A float-type sight gage is located near the filler and an electric gage with indicating unit is mounted on the instrument panel in the cab.

Fuel is supplied by a gear pump to each engine with returns for excess fuel. The fuel tank is electrically grounded.

An 11 1/2-in. locomotive bell is operated by an internal quick-acting pneumatic ringer, with an emergency hand cord. There are two pneuphonic horns, one at each end of the locomotive. Suitable brackets are installed for mounting classification or marker lights, with necessary plug sockets.

The main engine throttles are connected together and operated through one control lever which is located to the left and front of the operator. The throttle control lever and electrical controller are so interlocked that the controller can be moved only when the throttle lever is in the idling position. Group control switches are located directly in front of the operator. Engine starting, electrical control connections, auxiliary equipment, and all lights are controlled from these switches. The air brake operating valve is conveniently located at the operator's left.

A sloping instrument panel, properly illuminated, is located in front of the operator. On this panel are mounted the air gages, engine temperature gages, oil pressure gages, traction-motor ammeters, battery ammeter and fuel gage. The sander operating valve, bell-ringer valve,

window-wiper valves and whistle control are conveniently located. All control apparatus is located at one station although a second control station can be installed if desired.

General dimensions and weights of new D-B diesel-electric switcher.

Wheelbase of truck (rigid)	8 ft. 0 in.
Wheelbase total	32 ft. 0 in.
Length over couplers	42 ft. 0 in.
Height above rail with center cab (max.)	14 ft. 0 in.
Height top of underframe to rails	4 ft. 10 in.
Height cab floor to rails	7 ft. 6 in.
Height engine compartment top to rail	11 ft. 4 in.
Length of cab—inside	9 ft. 6 in.
Width of cab—inside	9 ft. 10 in.
Width of engine hood—outside	10 ft. 0 in.
Minimum curve	100 ft. 0 in.
Maximum speed	40 m.p.h.
Total weight in working order (all on drivers)	210 000 lb.
Journal load per driving axle	52 500 lb.
Tractive force at starting	
30 per cent adhesion	63 000 lb.
Tractive force at starting	
25 per cent adhesion	52 500 lb.

MISCELLANEOUS INFORMATION.

[62. (01 & 621. 133.7)

1. — Pitting and corrosion in locomotive boilers (*).

(*Railway Age.*)

Cause of and remedy for boiler corrosion, with special reference to the status of embrittlement investigation, is reported by American Railway Engineering Association.

It is generally recognized that the quality of water used in the boilers of locomotives on American railroads is an important factor in controlling economical operation, not only through its effect on the condition of the power, on boiler repairs and on fuel consumption, but also because such conditions directly affect train operation and the movement of traffic.

The committees of the various railroad associations, particularly those of the Engineering and Mechanical divisions of the A. A. R., have done much to improve boiler-water conditions, and the results are apparent on the railroads which have put their recommendations into effect. Scale accumulation and leaking troubles, which formerly occurred to such an extent as to interfere directly with train operation, have been largely eliminated by proper chemical treatment of water, and corrosion in boilers has been materially reduced.

(*) Abstract of the report « Cause of and remedy for pitting and corrosion of locomotive boiler tubes and sheets, with special reference to status of embrittlement investigation », by Subcommittee 3, A. R. E. A. Committee XIII — Water Service, Fire Protection and Sanitation, R. E. Coughlan, chairman. The report was published in Bulletin 404, A. R. E. A., June, July, 1938, pages 73-96.

Cracking of boiler shells.

During the past twenty years, with the use of larger engines, increased boiler pressure, longer engine runs and greater utilization of motive power, one type of defect which has developed on occasional engines in various localities is cracking in the boiler shells, these cracks starting from the rivet holes in the stressed metal either in the boiler-shell laps or butt straps, and in some cases extending over considerable areas along the seams.

Such cracks not only cause an unsafe condition if they are not located and repaired promptly, but also result in considerable increased expense for repairs, since heavy patches or new shell courses are frequently necessary. While accurate figures as to the damage caused by such defects are not available, a conservative estimate indicates resulting losses for the country as a whole in excess of \$ 500 000 a year; however, this figure would be increased greatly in case of any serious accident.

This type of cracking has been very difficult to explain. It has occurred in occasional engines operating in a territory where the water quality is rated as relatively good as well as in regions where the quality is recognized as bad. Because this action has not been at all consistent with respect to locality and water conditions, the solving of the problem has been delayed, and the question of design and workmanship as well as the quality of the boiler material appeared to be closely involved.

Similar experience with the boilers of stationary power plants was noted at about the same time, or possibly a little earlier. Studies at the University of Illinois Engineering Experiment Station, reported in Bulletins Nos. 94, 155, 177 and 216, and financed by boiler manufacturers and later by utility companies, have indicated that such cracking was either caused or accelerated by an unsatisfactory quality of the water and was due principally to sodium-hydroxide concentration in the boiler water. These experiments as well as case histories which were investigated indicated that such cracking, when caused by concentrated caustic soda, could be prevented by carrying definite ratios of sodium sulphate in the water. On the basis of these reports, the American Society of Mechanical Engineers amended its boiler code in 1926 to include a recommendation for carrying arbitrary ratios of sodium sulphate to sodium hydroxide in boiler waters for various pressures.

The results obtained in the operation of locomotive boilers have indicated that this A. S. M. E. recommended ratio is not applicable, and has further raised the question as to its correctness for any type of high-pressure boiler. Meanwhile, cracked locomotive boilers continued to be reported in cases where the quality of the water used met the A. S. M. E. code, and was otherwise deemed satisfactory.

Study inaugurated in 1923.

In 1923, a group of engineers and chemists interested in the treatment of boiler feedwater inaugurated a study to improve methods of treatment for the purpose of effecting greater economy in power-plant operation and in steam railroad service. This movement was sponsored officially by the American Boiler Manufacturers Association, the American Railway Engineering Association, the American Society of Mechanical Engineers, the American Society for Testing Materials, the American Water Works Association, the Edison Electric Institute and the United States Navy.

In 1932 this group organized a subcommittee under the chairmanship of J. H. Walker,

engineering assistant to the general manager of the Detroit Edison Company, Detroit, Mich., which inaugurated a research investigation for the purpose of obtaining more definite and fundamental information on this important subject. With contributions obtained from various industries, a research program was started under a co-operative agreement with the Bureau of Mines at its New Brunswick, N. J., experiment station, and was under the supervision of its director, Dr. E. P. Partridge, the work being carried out by Dr. W. C. Schroeder. As the majority of the committee, at that time, was strongly convinced of the reliability of the American Society of Mechanical Engineers code recommendation, the first steps taken were to determine the solubility of sodium sulphate in boiler-water salines at high temperature, which would permit more definite control than the arbitrary figures in the American Society of Mechanical Engineers' recommendation.

Results of investigation.

In the course of these solubility studies, the results of which have been reported in the scientific literature, it was found that chemically pure caustic soda did not have an embrittling action on boiler steel as originally reported. This led to further investigation of the actual embrittlement reaction and it was found that it was necessary to have silica or some related compound present in the caustic soda if intergranular corrosion and embrittlement of the metal under stress were to be effected.

Interest in this work increased, and further experiments developed that sodium sulphate had but a very limited effect in retarding the intergranular corrosion of stressed steel by concentrated sodium hydroxide-sodium silicate solutions, which was in line with the experience in railroad practice. The work was continued under the direction of Dr. W. C. Schroeder after Dr. E. P. Partridge left the service of the Bureau of Mines, and the study was transferred to the new building of the Bureau of Mines at College Park, Md., in 1937.

The Water Service Committee of the American Railway Engineering Association has kept in close touch with this research investigation since its inauguration. An article by the investigators, Dr. W. C. Schroeder, A. A. Berk and R. A. O'Brien, published in A. R. E. A. Bulletin No. 404, June-July, 1938, gives a brief résumé of the work conducted to date, which appears to have reached the following status as affecting railroad practice :

(1) The work has demonstrated conclusively that there is a definite possibility of intergranular corrosion in steel boiler plate under tension which was formerly incorrectly termed « caustic embrittlement », and this can be caused by exposure of steel boiler plate to the presence of excessive concentration of certain salts in boiler water. This fact had been seriously questioned before this research was started, and this uncertainty had materially delayed studies leading to the finding of a remedy.

(2) The work further demonstrates that caustic soda, which is the chemical usually maintained in boiler water to prevent scale and corrosion, will not cause intergranular corrosion except at excessive concentration and not then unless silica or some correlated element is present. This will permit railroad water chemists to continue using the most economical means available, without question, for the control of incrustation and corrosion.

(3) The work has further demonstrated that sodium sulphate does not afford protection against intergranular corrosion in locomotive boiler service, even when present in amounts greatly exceeding the recommended sulphate-alkalinity ratio of the A. S. M. E. boiler code. This will relieve railroad water chemists of the incentive to maintain this high ratio by adding sodium sulphate to boiler water, and will also permit a lessening of the foaming tendency in the boiler water by thus decreasing the amount of dissolved solids accordingly.

(4) The work has further demonstrated that none of the common inorganic salts generally available will afford appreciable protection against intergranular corrosion of

steel under tension. However, laboratory experiments with various organic chemicals have shown that definite protection can be obtained by the presence of a small amount of lignin compounds, which explains the highly satisfactory results secured on the Chicago and North Western from the use of such material. Tannin compounds of the cutch and quebracho type will also afford protection, while tannins of the oak or chestnut extract series do not appear as favorable. Wide scale tests of the possibilities of these findings are now being made on a number of railroads, although the experience on the Chicago and North Western would appear to demonstrate the benefits of such practice.

Difficulties have been encountered in following up these tests due to problems in properly proportioning the material to the water and in making a chemical check test for control. However, close co-operation is being maintained with the research workers who have been most helpful in checking and recommending procedures.

It is still necessary to develop a large amount of information in order to insure successful prevention of intergranular corrosion or embrittlement and the cracking of stressed boiler steel due to water conditions. These research studies at the Bureau of Mines have been given consistent able attention and are characteristic of the highest type of fundamental research work, and the personnel in charge is particularly competent and admirably qualified for this type of work. The information developed to date is of fundamental importance. The successful application remains to be generally proved and accepted in practice.

To date, various industries and casualty insurance companies throughout the country have contributed approximately \$ 30 000 and the Association of American Railroads has supplied an additional \$ 15 000 for carrying out this co-operative research investigation at the Bureau of Mines.

The Water Service Committee has recommended that an additional appropriation be made by the Association of American Railroads to assist in continuing the investigation

for one more year. It is hoped that it will be possible to continue this investigation in order to secure the co-operation of this trained force in helping to overcome completely the consi-

derable trouble and expense as well as the hazards that result from embrittlement and cracking of stressed boiler steel due to intergranular corrosion.

[628. 215 (.494)]

2. — The Brown-Boveri "Simplex" bogie for electric traction.

(*Engineering.*)

For many years bogies for motor coaches followed conventional lines, with only an occasional departure from the normal. In the past few years, however, there has been an effort to break new ground with the object of securing easier riding, less noise and greater comfort for passengers, and thus off-setting, to some extent, in these days of competition, the disadvantages possessed by street cars and inter-urban railways in comparison with other forms of transport, such as the motor car, motor 'bus, or trolley 'bus.

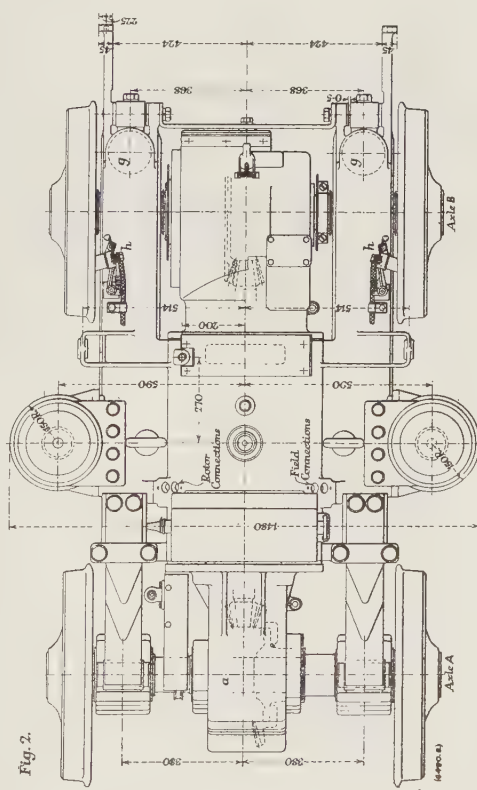
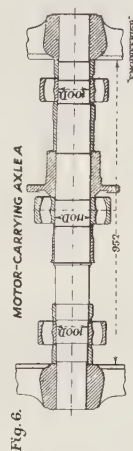
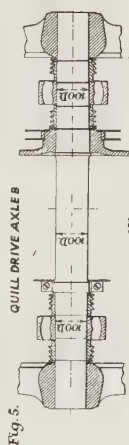
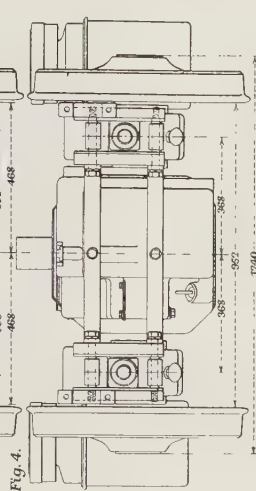
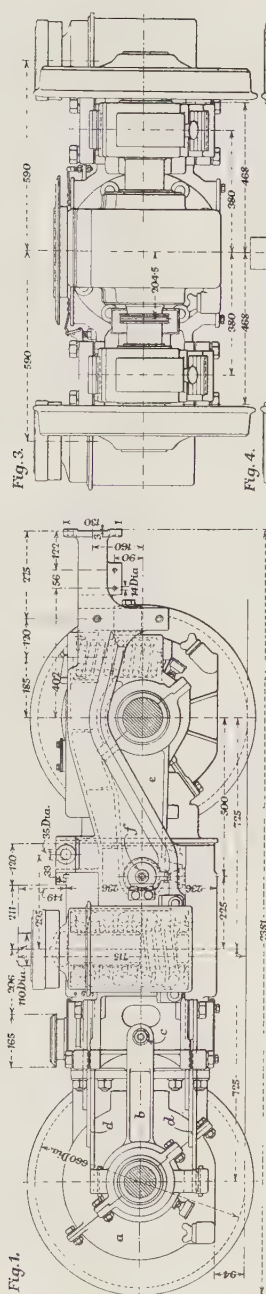
Some six years ago, Messrs. Brown, Boveri and Company, Baden, Switzerland, introduced a design embodying radical departures, the results of which proved so satisfactory that a first order for two motor coaches was increased by a further batch of ten. In the interval the design has been greatly improved so as to adapt it to a heavier class of stock and heavier axle loading. It is now suitable for more important service and has been adopted by the Biel-Meinisberg line in Switzerland, a coach so fitted being shown in fig. 7.

The new bogie is illustrated in figs. 1 to 6 and figs. 8 to 11. It is a complete departure from the usual motor bogie with nose suspension, as will be readily grasped when it is stated that the motor is arranged longitudinally, the two axles being driven by bevels at each end of the motor shaft. There is no framing in the usual sense of the term, the motor casing acting as the chief component. The motor casing is provided at one end with an extended casing which is supported at the

centre of one axle, while it is spring-borne at the other end of the bogie at each end of the second axle. Dealing with the former arrangement first, it will be seen from figs. 1, 2, 6 and 10 that the motor-casing extension *a* is supported in the middle of the axle by a large barrel-roller bearing, and at the same time is provided with two similar bearings, one on each side inside the wheels, housed in radius yokes *b*. The latter are pivoted to pins *c* fixed to the main housing, and in order to allow for slight lack of adjustment of the three bearings, the pins *c* are fitted with rubber pad mountings. As will be seen, the axle and frame are maintained in their correct relationship by the large horizontal leaf springs *d, d*, which allow for slight unevennesses of the track. The drive is transmitted at this end of the bogie, from the motor shaft, through the bevel and large crown wheel direct to the axle, shown dotted in fig. 2 and in the photograph reproduced in fig. 10.

At the other end of the bogie greater relative movement is permitted by means of the Brown-Boveri spring-quill drive. This drive is shown in fig. 11. It consists of two parts, one of which has six projecting lugs and is a shrink fit on the driven axle. The lugs engage with spring buffers fixed to the back of the large crown wheel which revolves on a quill fixed in the casing, thus ensuring correct meshing of the bevels, etc.

This axle is carried by two barrel-roller bearings, shown in fig. 5, provided with the large-radius yokes *e*, fig. 1, hinged again at



« Simplex » bogie for electric traction.

the pins *f*, and fitted with rubber mountings as in the previous case. The yokes accommodate spring boxes in which helical springs are housed, these taking the load on the frame on each side at *g* and *g*, fig. 2. The drawbar pull is transmitted through the usual king-pin mounted on the motor casing, and the weight of the coach body is taken by two large spring boxes, one on each side of the bogie, as shown in figs. 1, 2, 3, 8, and 9. The heads of the spring boxes are spherical, and the coach side-bearings are cupped to corres-

pond. The system simplifies braking, since it is sufficient to brake one set of wheels, the retardation effect being transmitted to the other through the driving shaft. Service control is accomplished by means of electric resistance brakes.

The whole of the drive at each end is housed in a dirt- and dust-proof casing. All these parts have automatic closed-circuit lubrication. In the case of the quill drive, oil is first supplied to the quill bearing, passing thence to the crown wheel and spring drive. There are

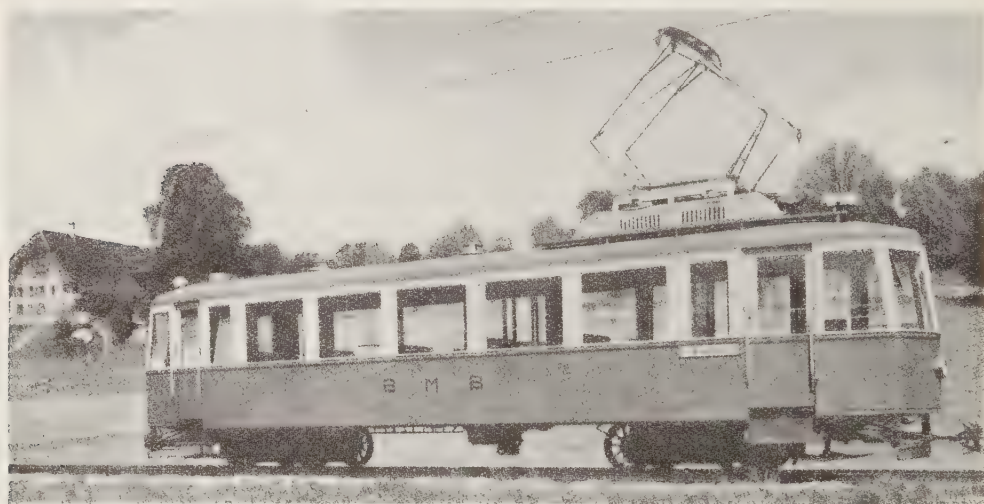


Fig. 7. Motor coach on the Biel-Meinisberg Railway.

pond and are provided with rubber shock-absorbers.

It will thus be seen that the design embodies what is virtually three-point suspension. The quill-drive axle is allowed sufficient movement to prevent it striking any other part, the actual range being limited by rubber pads. The arrangement of the motor results in both axles being driven, though the drive is resilient instead of rigid. Better use is therefore made of adhesion, since when the pull of the drawbar tends to alter the axle loading the coupled effect of the axles comes into

play. The system simplifies braking, since it is sufficient to brake one set of wheels, the retardation effect being transmitted to the other through the driving shaft. Service control is accomplished by means of electric resistance brakes.

The motor bogie illustrated, fitted with a 100-h.p. motor and wheels 660 mm. (2 ft. 2 in.) in diameter, has a wheelbase of 1.50 m. (4 ft. 11 in.) and weighs less than 3 000 kgr. (6 600 lb.).

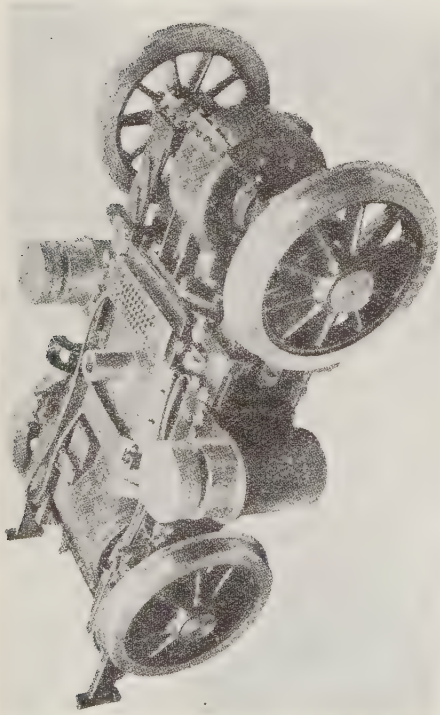


Fig. 8. -- General view.

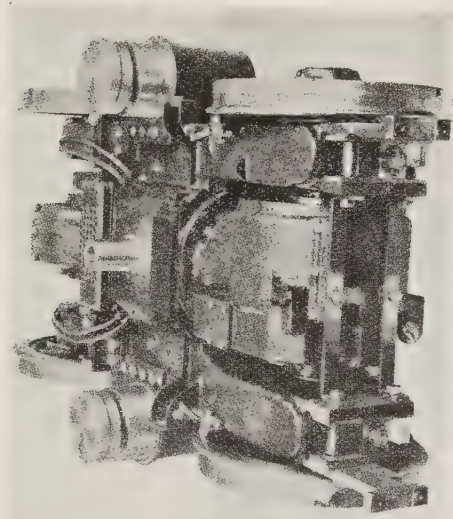


Fig. 9. -- Quill-drive end of bogie.

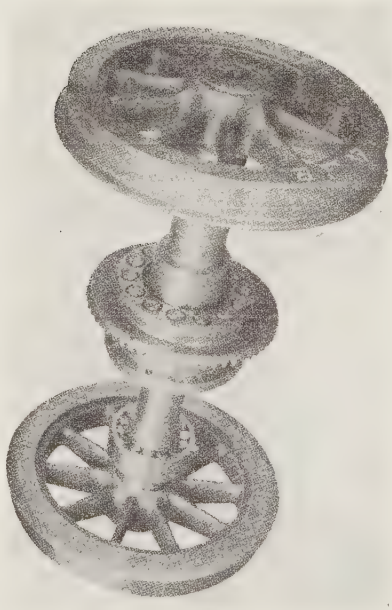


Fig. 10. -- Motor-carrying axle.

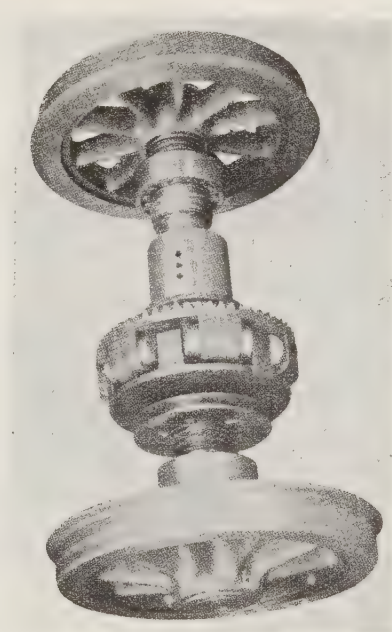


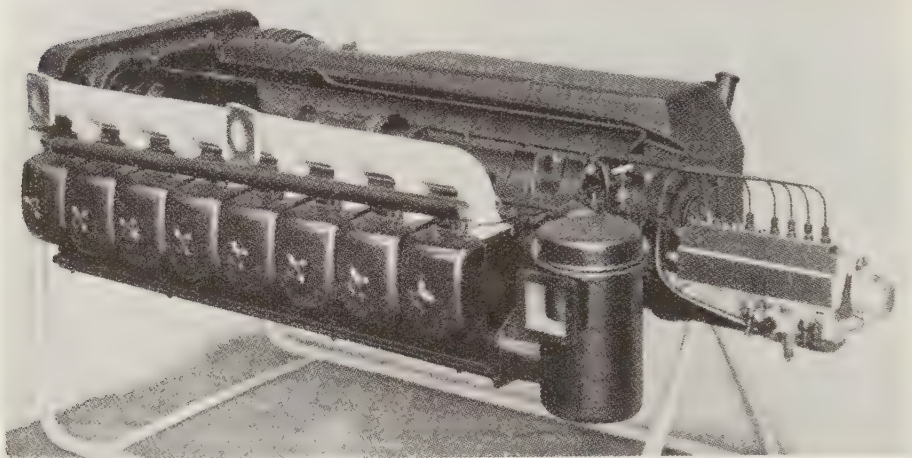
Fig. 11. -- Spring quill drive.

[621. 45 (.42)]

3. — A single-bank horizontal engine (Humboldt-Deutz) for light railcar work.

Sensitive hydraulic governing over speed range of 400 to 2 000 r.p.m.

(Diesel Railway Traction, Supplement to The Railway Gazette.)



An horizontal engine for light railcar work has been introduced, by the Humboldt-Deutz-motoren A. G. Like the Leyland road transport and the Vomag engines it has only one bank of cylinders, and is, in fact, simply the Deutz eight-cylinder vertical high-speed engine turned over on its side and with the absolute minimum of changes.

The principal alteration is in the sump, which previously was simply an oil trough, whereas now it must assist the crankcase in its function as the engine frame-work. It is now of cast iron, and large inspection doors in the side (or what in a vertical engine would be the bottom) enable the connecting rods and pistons to be withdrawn without breaking the joint between the sump and the crankcase. Another alteration is in the position of the fuel pump, which became located on the underside when the engine was turned over; the pump, of Deutz manufacture, has been transferred to one end, and is now driven directly by the camshaft. Similarly, the air, lubricating oil, and fuel filters have been mounted at the same end, so that all parts needing inspection or replacement are located together in a convenient position. On account of the horizontal position, the valve stems and

rockers have been connected to the pressure lubrication system. The Deutz fuel pump is interchangeable in its attachment with the proprietary fuel pumps.

Eight cylinders 130 mm. by 170 mm. (5.12 in. by 6.7 in.) are used, and they are fitted with precombustion chamber heads cast individually. At the top speed of 1 600 r. p. m. the engine output is limited to 175 B.H.P. for railway applications, but the maker sets the engine to 200 B.H.P. at the same speed for road or other purposes. The weight with electric starting motor and dynamo is 1 300 kgr. (2 870 lb.), equivalent to 16 1/2 lb. per B.H.P. for the railway engine. The overall dimensions are 620 mm. (24 1/2 in.) high, 1,275 mm. (4 ft. 2 1/2 in.) broad, and 2.5 m. (8 ft. 3 in.) long. At the top railway output of 175 B.H.P. at 1 600 r. p. m. the fuel consumption is 203 gr. per B.H.P.-hour, the m. e. p. 77 lb. per sq. in. and the normal exhaust temperature about 450° C. The minimum fuel consumption is 200 gr. per B.H.P.-hr. over the range of 150 B.H.P. at 1 225 r. p. m. to 165 B.H.P. at 1 400 r. p. m. The point of maximum torque and m. e. p. is 1 120 to 1 140 r. p. m.

NEW BOOKS AND PUBLICATIONS.

[656. 255]

SCHMIDT (Dr. Walter), President of the Dresden Area of the Reichsbahn. — **Leitgedanken der Eisenbahngütertarifpolitik mit Ausblicken auf die Tarifpolitik der Reichsbahn im Sächsischen Wirtschaftsgebiete** (*Guiding principles of the goods rates policy with special reference to the rates policy of the Reichsbahn in the industrial districts of Saxony*). — 1938, Leipzig; Felix Meiner, Publisher. (Price : 0.80 Reichsmark.)

This brochure is one of a series of studies published by the Institute for the advancement of the science of transport, attached to the University of Leipzig.

Its object is to show how the rates policy and the structure of the rates serve the general economic life of Germany.

The author recalls that at the beginning the railways, which formed isolated undertakings, were mainly operated on commercial principles and for profit. Subsequently the position gradually became modified and opinions changed. The railways increased in size and in density, so that they made agreements with each other and sometimes competed against each other. This made it necessary to modify the rating systems. The extension of the railway networks and the amalgamations which took place had the effect of enabling poor districts and lines with little traffic or difficult sections to benefit by the same low rates as the prosperous lines.

The unification of the country and the

railway system led to the general application of the differential rates which Prussia had already been able to allow her industries and population to enjoy. The author quotes examples of services rendered by rates decreasing as the distance increases, which he calls the vertical scale. Besides these, he shows the compensation made between costly goods and cheap goods by means of rates based on the value, or the grouping of goods into classes, which he calls the horizontal scale.

Elsewhere he points out the great use made of special rates, above all when it is a question of goods for export via the sea ports.

One such extensive application is intended to encourage industry in Saxony.

Finally the author shows the rating problems raised by the new frontiers, and defines the position of the Deutsche Reichsbahn in the face of competition from other methods of transport.

E. M.

[656. 261]

Dr.-Ing. CULEMEYER, Reichsbahndirektor. — **Die Eisenbahn ins Haus. Die Beförderung von Eisenbahnwagen und Schwerlasten mit Strassenfahrzeugen** (*Door-to-door rail transport. Transport of railway wagons and special heavy loads by means of road vehicles*). — One volume (11 $\frac{3}{4}$ × 8 $\frac{3}{4}$ inches) of 296 pages with 371 figures. — 1939; Published by Otto Elsner Verlagsgesellschaft, Berlin, Vienna, Leipzig. (Price : 28 Rm.)

Dr. Culemeyer's work is devoted to all the solutions put into practice, under trial, or merely suggested for obtaining door-to-door transport, by complete wagon loads and without transhipment of

the goods, by means of road vehicles belonging to the railway. He stresses the extremely rapid development of these new methods of transport on the Reichsbahn; from 1933 to 1938, by means of

special vehicles, this Company has been able to give door-to-door collection and delivery of 163 000 goods wagons and many particularly large or heavy consignments from very diverse branches of industry.

After the first chapter devoted to the genesis of the idea of getting door-to-door transport by means of railway vehicles, which could be worked on both rail and road, the book goes on to consider the different types of such vehicles, with two sets of wheels to enable them to run on both rail and road, especially the Willème-Coder road-rail wagons used in France. He also recalls the suggestion of an « articulated universal cargo carrier system » described by Mr. Wanamaker, Electrical Engineer of the Chicago, Rock Island & Pacific Railroad, in his report on railcars, discussed at the 1935 Enlarged Meeting of the Permanent Commission of the International Railway Congress Association ⁽¹⁾.

The most important part of the book, however, is that devoted to road vehicles equipped to carry railway wagons, and drawn by tractors. After recalling the first attempts to carry railway vehicles on the roads, the author analyses the principal patents taken out or put forward since 1907, in particular the solutions suggested in France by Barthélemy, those adopted by the Italian State Railways, and those of the Reichsbahn. A

special chapter is given up to a description of the vehicles used by the latter, full constructional details being given first of all of the trucks for wagons hauled by separate tractors, especially the two-truck vehicles with 16 wheels, which can carry up to 40 tons and the two-truck vehicles with 24 wheels which can carry up to 80 tons; then types of vehicles where part of the load is transferred to the rear pair of wheels of the tractor; and finally auto-tractor types. Special types with tipping apparatus are also examined.

Other chapters describe the different types of tractors used; the legal regulations affecting the circulation of this kind of transport on the roads, and an examination of the new stresses caused to bridges and roads thereby; a description of the wagon transshipment plant at stations, and finally the various kinds of special loads carried on the roads, such as boilers and reservoirs of large dimensions, bridge girders, boats, locomotives, etc... by means of vehicles and tractors of the same type as those used to transport loaded wagons.

The book contains a particularly large number of diagrams and photographs, which will enable railway users to appreciate the many different solutions offered by this new technique in the case of door-to-door transport.

A. C.

[636. 221]

LIPETZ (A. I.). — **Air Resistance of Railroad Equipment.** — A pamphlet (8 3/4 × 11 inches) of 34 pages with 43 figures. — Reprinted from the *American Society of Mechanical Engineers Transactions*, October 1937.

This investigation by Mr. Lipetz, Chief Consulting Engineer, in charge of research, American Locomotive Company, and non-resident Professor in Locomo-

tive Engineering, Perdue University, is certainly one of the most complete so far published on the question of the air resistance of railway equipment.

The author first of all reviews the historical aspect of the question, the fundamental principles of the theory of air

(1) *Bulletin of the Railway Congress*, June 1935.

resistance, and the first trials made in wind tunnels. He then deals with the tests made conjointly by the American Locomotive Company, the American Car and Foundry Company, and the J. G. Brill Company in the wind tunnel of the University of New York; he discusses the results and deducts therefrom the air resistance formulæ to be used in the case of the small-scale models used for such tests. These formulæ are then adapted to full-size stock; the author gives several simplifications which can be made in practice thereto, and he compares the results given by formulæ modified in this

way and those obtained from running tests. He then considers the power gains made possible by the adoption of streamlining.

The pamphlet also contains a very complete bibliography on the question of air resistance of railway equipment, as well as a review of the discussions which followed Mr. Lipetz's report to the American Society of Mechanical Engineers, during the course of which some of those best qualified to do so made several very interesting contributions towards the study of this question.

A. C.

[585. (02)]

PLACE (Pierre), former pupil of the Polytechnical School, Paris, Engineer, Head of the Locomotive Department of the Central Railway Equipment Designing Office (O. C. E. M.). — **Chemins de fer — Agenda Dunod**, 1939 (*Railways — Dunod Pocket Book*), (58th edition). One volume (4 × 6 inches) of CXLIV + 396 pages with 94 figures and one plate. — Dunod, Publisher, 92, rue Bonaparte, Paris (6^e). (Price: Bound in imitation leather: 25 French francs.)

Like its predecessors, the 58th edition of the Dunod Railway Pocket Book (1939) is a first class up-to-date encyclopedia on the *permanent way* (estimation of the probable traffic, cost of construction and operation, administrative formalities, design of the track, feed water supply equipment, etc.), on *traction* (train resistance, power of locomotives, loads, steam locomotives, railcars, electric traction, and ferryboats), on *rolling stock* (underframe and body, different types of passenger and goods stock, brakes, lighting and heating, etc...), and finally on the *operation* (traffic safety devices, rates, receipts and expenditure, taxes, statistical information).

The 1939 edition contains in particular the following studies :

- The 1937 Convention and the creation of the French National Railways Company.
- Table of weights and dimensions of the three standard types of rails.
- Locomotive trials: constant speed and indicated power method.
- Table of railcars in service on the 1st July, 1938.
- Corrected table of the leading dimensions of the principal metal coaches of the French Railways; lightened metal coaches.
- Air conditioning: equipment with compressor cooling plant.

